METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 57 No. 340 FEBRUARY, 1958 Monthly: Two Shillings and Sixpence

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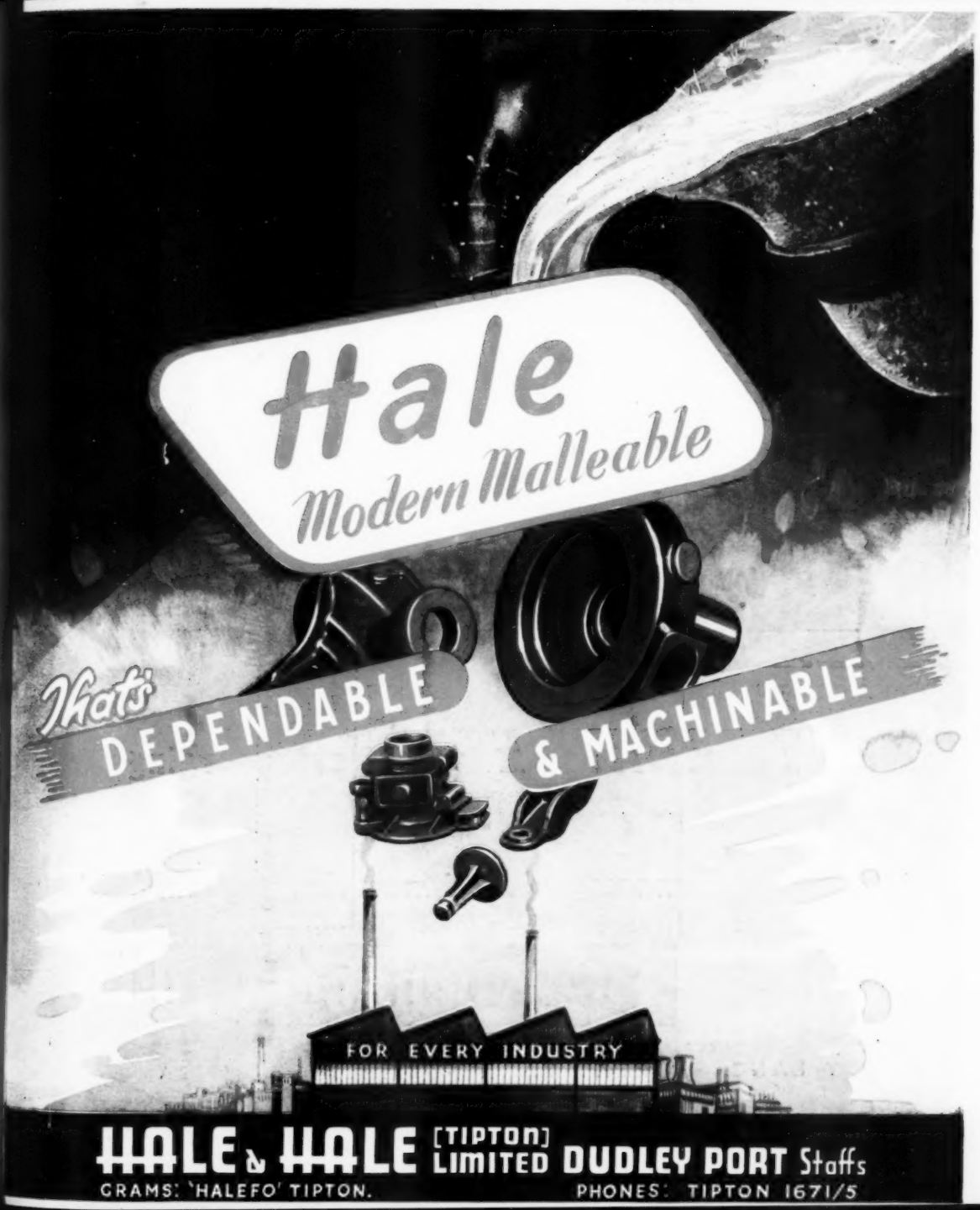

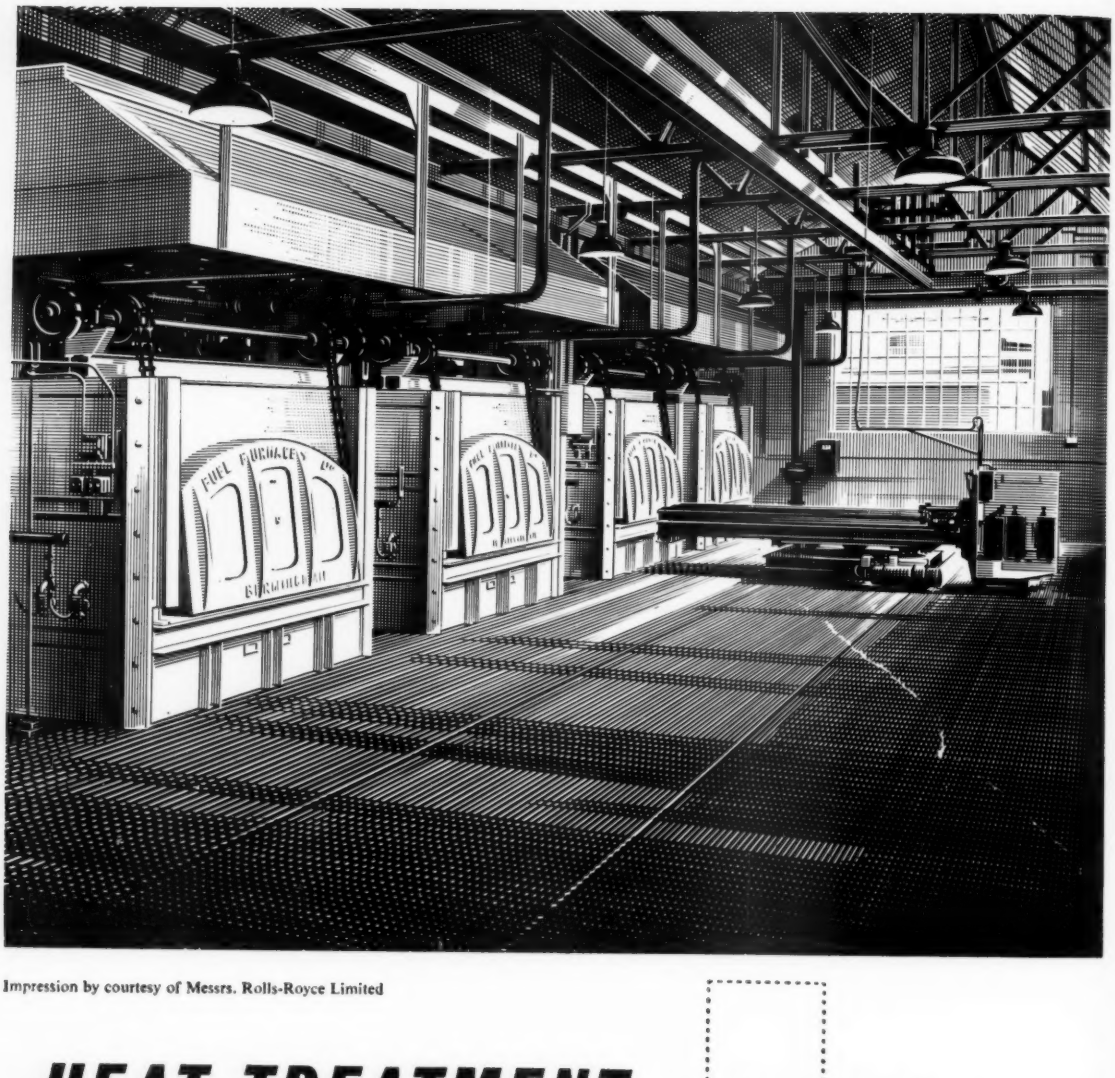

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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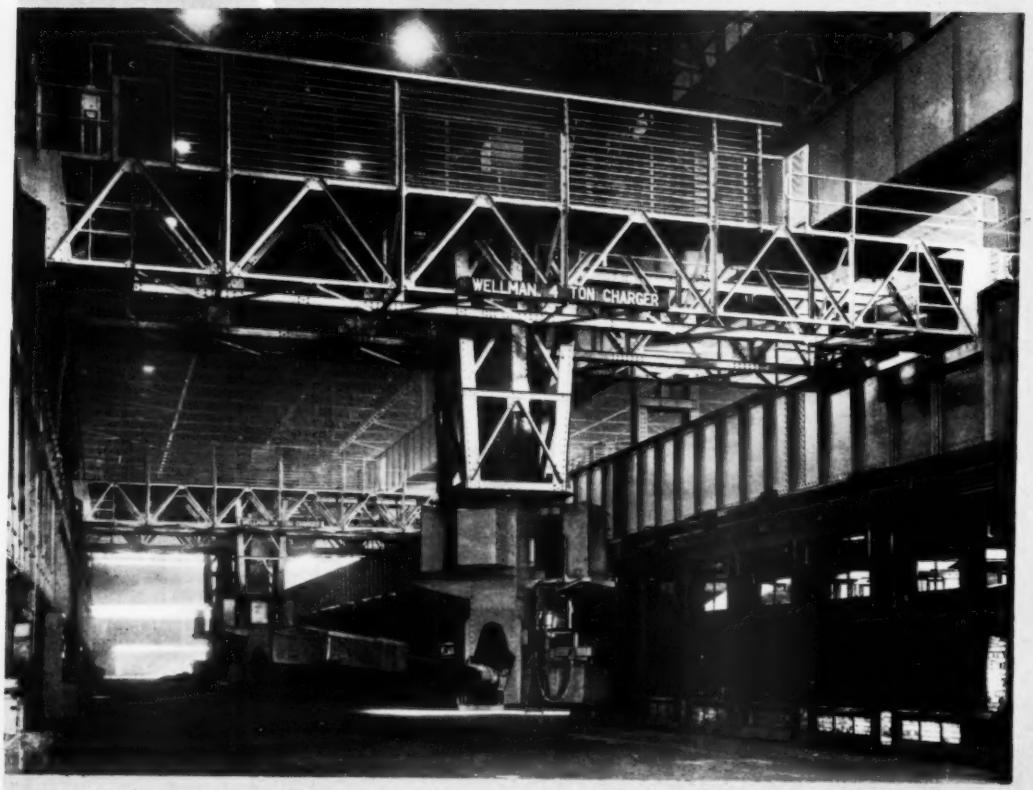

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

FEBRUARY, 1958 Vol. LVII. No. 340

Steel Progress and Prospects

DURING the first nine months of 1957, home consumers used some 1½% less steel than in the corresponding period in 1956, and this figure would have been larger had there not been an improvement in general industrial production from May onwards. The impact of this check to steel consumption was lessened by the fact that consumers and merchants increased their stocks, and by a fall in imports and a rise in exports. At an estimated figure of about 4 million ingot tons, exports are higher than they have been since the peak year of 1923.

Despite the fuel oil cuts during the early months of 1957, the output for the year at its estimated figure of 21·7 million tons represents an increase of a little over a million tons as compared with 1956. The increased production sprang mainly from an increase in plant capacity, which continued its post war growth. The industry had available a full year's use of the considerable quantity of plant first brought into operation during 1956, as well as the use for part of the year of important additions to capacity in every section of the industry, including the new iron and steel works at Ravenscraig in Scotland. As a result, however, of the weakening of demand, the estimated output of 21·7 million tons, is appreciably below the 22·4 million tons for which the industry had capacity available.

In the review of progress and prospects featured in the January issue of *Steel Review*, published by the British Iron and Steel Federation, it is emphasized that, in the light of the situation at home and the uncertain prospects abroad, it is more than usually difficult to assess the outlook for 1958. It looks, however, as though steel output will exceed the 1957 level of 21·7 million tons—which in a 53-week year such as 1958 would be equivalent to over 22 million tons—but demand is likely to hold output below the 23½ million tons for which the industry will have capacity available.

The Government's new economic measures have as yet made little impression on the steel industry, but, as their main weight falls on investment, which is a heavy steel user, their effect is bound to be felt as time goes on. On the other hand, on the strength of the high home demand for cars and a large influx of export orders, the motor industry seems likely to make considerable demands on sheet. It is rather difficult to estimate the net effect of various factors influencing steel demand but it seems unlikely that there will be any marked upward trend in the use of steel at home before the closing months of the year.

The possible slackening of home demand for a time will not halt the addition of further capacity, although the situation will be closely watched from the long term viewpoint. Special features of the 1958 plant commissioning programme are the substantial increase to be made in sinter capacity—over 4 million tons of new capacity is to come into use, with beneficial effects on blast furnace productivity—and the predominance of Bessemer converters and electric furnaces among the new steelmaking plant.

To close the gap between home demand and rising capacity, the steel industry will try to reduce imports and increase exports, mainly the latter. This will be no easy matter, as the world market for steel stands under the shadow both of uncertainty as to the course of business activity in the United States, and of the possibility of a further fall in commodity prices which would weaken the purchasing power of many of Britain's customers. Furthermore, more steel is likely to become available on offer from other exporting countries, and Continental producers in particular must be expected to press export sales vigorously in the coming months. There is also the possibility that the United States steel industry—for which a production rate of 70% of capacity is forecast for the first half of this year—many decide to seek export orders, although they did not do so in the 1953-54 recession. In spite of all these difficulties, the industry expects to increase exports above the post-war record figure. New capacity is strengthening the industry's competitive ability, and it must also be remembered that, hampered as it has been since the war by a variety of formal and informal restraints on steel exports, the British steel industry has never yet been free to deploy its full competitive strength in world markets.

A further possible result of the emergence of a gap between demand and rising capacity is the retirement of more obsolescent plant. The old tinplate hand mills have already been affected, not only because tinplate demand was disappointing, but also because of a considerable growth in output at the continuous mills, owing to the rapid working up of production at the new tinplate works at Velindre. Within the first nine months of 1957, the Steel Company of Wales and Richard Thomas and Baldwins either closed or announced the early closing of all their remaining hand tinplate mills. In all, the withdrawal of about 170,000 tons of capacity was announced in this period, leaving only about 100,000 tons of tinplate hand mill capacity in existence. Further, Richard Thomas and Baldwins have recently decided to close two of their older cold metal steel works, at Gorseinon and Cwmfelin, involving a withdrawal of some 200,000 tons of steelmaking capacity. These are only a beginning, and it is more than likely that other companies will take advantage of the present excess of capacity—temporary though it is likely to be—to review critically the life of particular items of plant.

Once the current confused situation has clarified itself, particularly in relation to events abroad, it may be possible to re-assess possible long-term demand for steel, but at the moment future trends are not sufficiently well established to merit any change in the development proposals already announced by the industry.

Meeting Diary

7th February

Institute of Fuel. "Some Aspects of Fuel Efficiency in Modern Blast Furnace Practice," by K. C. SHARP. South Wales Institute of Engineers, Park Place, Cardiff. 6 p.m.

11th February

Institute of British Foundryman, Slough Section. "Feeding Aids to Castings," by A. L. LOGAN. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7.30 p.m.

Institution of Engineers and Shipbuilders in Scotland. "Welded Ship Construction—Records of Common Fractures and their Causes," by H. R. GIBBS and G. M. BOYD. 39, Elmbank Crescent, Glasgow. 6.30 p.m.

Sheffield Metallurgical Association. "Developments in the use of Refractories at the Steel Division of the Steel Company of Wales," by G. M. WORKMAN. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

12th February

Incorporated Plant Engineers, Western Branch. "Oil Firing," by DR. G. J. GOLLIN. Grand Hotel, Bristol. 7.15 p.m.

Manchester Metallurgical Society. "Plastics versus Metals," by J. M. J. ESTEVEZ. Manchester Room, Central Library, Manchester, 2. 6.30 p.m.

13th February

Incorporated Plant Engineers, Merseyside and N. Wales Branch. "Non-Ferrous Welding," by E. A. FOREMAN. Exchange Hotel, Liverpool. 7.15 p.m.

Liverpool Metallurgical Society. "Wear in Cast Iron," by DR. H. T. ANGUS. Liverpool Engineering Society's Rooms, 9, The Temple, Dale Street, Liverpool. 7 p.m.

14th February

West of Scotland Iron and Steel Institute. "High Temperature Testing," by J. GLEN. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

17th February

Institute of Metal Finishing. "Health Hazards Associated with Metals Affecting the Finisher," by A. R. THOMPSON. Royal Society of Tropical Medicine and Hygiene, 26, Portland Place, London, W.1. 6.30 p.m.

Sheffield Metallurgical Association. "Low Carbon Bainitic Steels," by DR. K. J. IRVINE, Joint Lecture with the Society of Engineers and Metallurgists. Engineering Lecture Theatre, University, St. George's Square, Sheffield. 7.30 p.m.

Society of Chemical Industry, Corrosion Group. "Protection of Spraying and Dusting Equipment," by a REPRESENTATIVE of the NATIONAL INSTITUTE OF AGRICULTURAL ENGINEERING. 17, Belgrave Square, London, S.W.1. 6 p.m.

18th February

Institute of British Foundrymen, East Anglian Section. 'Mechanisation of a Small Jobbing Foundry," by R. BLANDY. Lecture Hall, Public Library, Ipswich. 7.30 p.m.

North East Metallurgical Society. "Modern Developments in Iron and Steelworks Refractories," by H. M. RICHARDSON. Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough. 7.15 p.m.

Sheffield Metallurgical Association. "Penetrant Methods of Inspection," by DR. R. SCHNURMANN. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

19th February

Institute of Fuel. The Melchet Lecture: "Nuclear Engineering: Some Difficulties in the First Ten Years," by SIR CHRISTOPHER HINTON, K.B.E. Institution of Civil Engineers, Great George Street, London, S.W.1. 5.30 p.m.

20th February

Incorporated Plant Engineers, Blackburn Branch. "Nuclear Reactors for Power Production," by J. A. DIXON. Golden Lion Hotel, Blackburn. 7.30 p.m.

Institute of Metals, Birmingham Local Section. "Neutron Irradiation Effects in Metals," by PROF. J. G. BALL. Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham. 6.30 p.m.

25th February

Institution of Engineers and Shipbuilders in Scotland. "Work of the Mechanisms, Engineering Metrology and Noise Control Division of M.E.R.L.," by C. TIMMS. 39, Elmbank Crescent, Glasgow. 6.30 p.m.

Sheffield Metallurgical Association. "Metallurgical Requirements of the Aircraft Industry in Present Conditions," by G. MEIKLE. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

26th February

Institute of British Foundrymen, London Branch. Discussion on Test-bars, initiated by D. MORRIS. Constitutional Club, Northumberland Avenue, London, W.C.2. 7.30 p.m.

Institute of Fuel. "Boiler Water Treatment: A Formula for the Control of Sludge and Scale in Internal (Carbonate) Treatment," by DR. J. A. GRAY and "Boiler Water Treatment: A Formula for the Control of Sludge and Scale in Internal Carbonate Treatment: Experiments in a Laboratory Boiler," by E. F. THURSTON and L. FURNIVAL. Institution of Civil Engineers, Great George Street, London, S.W.1. 5.30 p.m.

Manchester Metallurgical Society. "Metallurgy of Tantalum, Niobium and Beryllium," by DR. G. L. MILLER. Manchester Room, Central Library, Manchester, 2. 6.30 p.m.

Society of Chemical Industry, Corrosion Group. "Stress Corrosion Cracking of Stainless Steels," by T. P. HOAR and J. G. HINES; "Stress Corrosion Cracking of Carbon and Low Alloy Steels," by R. N. PARKINS. Joint Meeting with Newcastle Section. Stephenson Building, King's College, Newcastle-upon-Tyne. 2.30 p.m. and 6 p.m.

27th February

Incorporated Plant Engineers, Sheffield and District Branch. "Atmospheric Pollution in Industry," by W. HERRING. Grand Hotel, Sheffield. 7.30 p.m.

Institute of Fuel. "The Use of Additives to Reduce Boiler Fouling and to Prevent Low Temperature Corrosion in Modern Oil-fired Boilers," by W. D. JARVIS. James Watt Institute, Great Charles Street, Birmingham, 3. 6.30 p.m.

Southampton Metallurgical Society. "Non-Destructive Testing of Metals," by DR. HANSTOCK. Southampton University. 7.15 p.m.

28th February

Institute of Metal Finishing. "High Speed Bright Silver," H. E. HUTCHINSON. Grand Hotel (Fitzwilliam Room), Sheffield. 7 p.m.

4th March

Incorporated Plant Engineers, Peterborough Branch. "Electronic Control of Machine Tools," by N. MILNE. White Lion Hotel, Church Street, Peterborough. 7.30 p.m.

Institute of Metals, Oxford Local Section. "Nucleation and the Cast Structure," by DR. V. KONDIC. Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

Institute of Metals, South Wales Local Section. "Metals for High Temperature Service," by DR. W. BETTERIDGE. Department of Metallurgy, University College, Singleton Park, Swansea. 6.30 p.m.

Sheffield Metallurgical Association. "The Application of Stable and Radioactive Isotopes in Analytical Chemistry," by A. A. SMALES. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

6th March

Institute of Metals, Birmingham Local Section. "The Metallurgy of Steel for Deep Drawing and Pressing—Part II," by A. J. K. HONEYMAN. College of Technology, Gosta Green, Birmingham. 6.30 p.m.

Institute of Metals, London Local Section. "High Purity Iron," by B. E. HOPKINS. 17, Belgrave Square, London, S.W.1. 6.30 p.m.

Leeds Metallurgical Society. "Some Metallurgical Problems of Nuclear Energy," by DR. H. K. HARDY. Lecture Room C, Chemistry Wing, The University, Leeds, 2. 7.15 p.m.

10th March

East Midlands Metallurgical Society. "Continuous Casting of Steel," by a MEMBER OF THE STAFF OF THE BRITISH IRON AND STEEL RESEARCH ASSOCIATION. College of Art, Green Lane, Derby. 7.30 p.m.

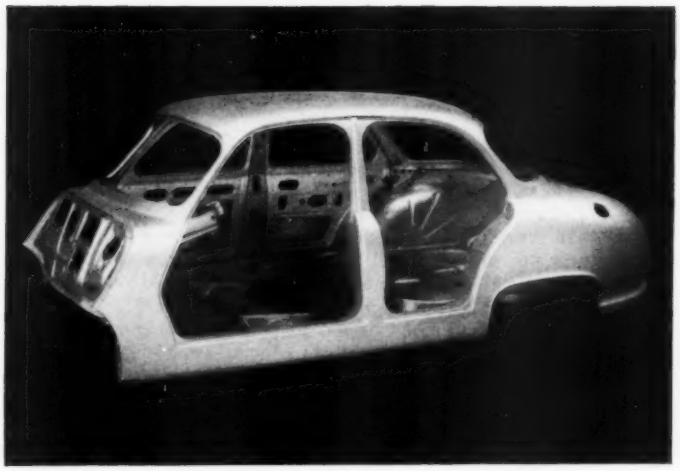
Institute of Metals, Scottish Local Section. "A Metallurgist in the Chemical Industry," by L. POWELL. Followed by the Annual General Meeting. 39, Elmbank Crescent, Glasgow, C.2. 6.30 p.m.

North East Metallurgical Society. "Recent Advances in Metallography," by DR. D. MCLEAN. Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough. 7.15 p.m.

The Use of Aluminium and its Alloys in Private Cars

By R. K. Bolton, M.A., A.M.I.Mech.E.

Sales Development Division, Northern Aluminium Co., Ltd., Banbury.



Partly-completed body shell of the Dyna-Panhard 54 car, which was spot and argon-arc welded in aluminium and aluminium-magnesium alloys.

Although wrought aluminium products are used extensively in commercial vehicle body work, less aluminium has been used per private car since the war for economic reasons. The author discusses the technical and economic aspects of the use of both wrought and cast aluminium alloys in bodywork, castings, radiators, trim, electrical systems and bearings.

IT is said that there is nothing new in the motor industry, and this is so nearly true that a precedent can be found for the manufacture of almost every component of the motor car from an aluminium alloy. Historically, even in the very early days of the industry, aluminium was extensively used for castings and panelling, since its properties of workability and low weight were well appreciated. In fact, it is likely that the weight of aluminium used per vehicle was far higher in those days than it is now. This statement refers primarily to private cars and remained true until the end of the 1920's.

Cars were then luxuries and were built in relatively small numbers so that, one suspects, the first cost of materials was not of great importance. But these vehicles were often efficiently designed, and it is worth recording that the early three litre Bentleys, which were large cars, weighed less than a ton. At the other end of the scale, the Austin Seven saloon of the 1920's cost around £100, according to equipment, yet used a formidable list of components in aluminium, including :

Body panels (except wings and bonnet)	Pistons
Crank case	Bell-housing and gearbox
Timing cover	Steering-box and wheel
Inlet manifold	Spring hangers
Window channels	Water offtake
Running board treadplates	Brake shoes

This state of affairs altered when the industry suffered its setback from depression and had to make radical changes to its type of product. The advent of deep drawing steel played a large part, too, and led to the adoption of mass-produced pressed steel bodywork. Habit dies hard, and aluminium castings continued in wide use until the war ; certainly any car with sporting pretensions used aluminium for its cylinder head on thermal grounds. For economic reasons, less aluminium has been used per car since the war, although, with the increased production of cars, tonnages have continued to rise.

Today, the entire motor industry, including the commercial vehicle manufacturers, consumes about 54,000 tons of aluminium annually, mostly (to the tune of 70%) in the form of castings. This implies an average of over 120 lb. of aluminium per vehicle made. This may seem large and, whilst it must be borne in mind that substantial uplift has been given to this average by the wrought products used in commercial vehicle bodywork, the average weight of castings supplied remains at over 80 lb. per vehicle.

The Technical Argument for Aluminium

The most obvious advantage is that of weight saving and, logically, aluminium should replace heavier metals in almost every transport application. The economics are not obvious at first glance and few people who use motor vehicles appreciate how weight can add to overall cost.

The resistance to motion of a moving vehicle is made up of two components, air drag and rolling resistance. The first is dependent on frontal area and the square of velocity, whilst the second is a function largely of weight. For simplicity, rolling resistance can be taken to be around 50 lb./ton, and it is in the reduction of this resistance that aluminium's economies lie. An example may be of help, so let us consider an average family car weighing 1 ton and cruising at 50 m.p.h. It so happens that at this speed air drag and rolling resistance are roughly equal, and each stands at about 50 lb. (at lower speeds rolling resistance, remaining constant at 50 lb., will predominate : at higher speeds air drag will increase above the 50 lb. mark). A reduction in the weight of this car of 10% will drop the rolling resistance to 45 lb.

and the total resistance to motion will then be 95 lb., 5% lower than before.

An immediate result is that the power required to drive the car falls by 5%, and with it the fuel consumption. Indirect savings will accrue from reductions in the power needed to accelerate the car, and in general wear and tear of tyres and mechanical components. If the weight reduction is planned at the design stage, a snowball effect can be achieved by reducing the size of most of the mechanical components on the car. The saving in fuel alone will be £12 10s. 0d. in 30,000 miles, and will more than offset the extra first cost involved in saving 2 cwt. This latter could be achieved by using 150 lb. of aluminium to replace 375 lb. of steel.

The ratio of sprung to unsprung weight of a car is, or should be, one of its vital statistics. The unsprung masses are those in contact with the road and they work on the main mass through the springing medium. Even a small reduction in their inertia will have marked effects on road holding, steering, braking, acceleration, comfort, tyre wear and the fatigue life of the vehicle's components: reduction of unsprung weight was one of the main points which led designers to specify the more expensive independent suspension. Aluminium could help to make big improvements in all these factors were it used for wheels, brakes, axles or suspension arms. So aluminium alloys, by saving weight, make technical and economic cases for themselves in road vehicles: the saving of unsprung weight is doubly important.

The superiority of aluminium over steel under corrosive conditions is certainly of more interest to commercial vehicle bodybuilders than to car manufacturers, so this aspect can be omitted for the present though, other factors apart, it will always prove a boon to the car owner.

The machinability of aluminium is often neglected, but can bring big savings in labour costs and overheads. In general, peripheral cutting speeds for drilling, turning or milling aluminium alloys can be three or four times as high as those for mild steel or cast iron, provided that the machine tool concerned has the necessary range of speed. This factor alone can permit aluminium to undercut iron on price, as in the specific instance of a half-crank-case. This raw casting cost 100 units in aluminium and 62·5 in iron, but the machining and overheads added 50·5 units to the cost in iron and only 11·5 units to the aluminium casting: overall, then, there was a saving in weight of 60% and in cost, of 1·5%.

The electrical conductivity of aluminium is high, and it has an advantage over copper where weight and cost are concerned. At present an aluminium conductor is about half the weight and price of a copper one, though more bulky and requiring additional insulation.

Similarly, the thermal conductivity of aluminium is more than four times that of steel or cast iron, so that wherever heat is generated locally and must be carried away, as in cylinder heads, brakes or bearings, it has a technical advantage. In fact, although aluminium used to be thought almost a necessity for the cylinder heads of high-output engines, research on combustion problems has shown that iron is usable up to compression ratios of about 10 : 1. This figure may be approached in a few years and could demand the reintroduction of aluminium heads.

The coefficient of thermal expansion of aluminium is normally something of an embarrassment, but occasionally it has its uses. For example, in cylinder blocks it might prove of great value because the bore and the piston could be made to expand at the same rate.

The low modulus of elasticity of aluminium means that deflections under load must be carefully watched during design, but once more there are saving graces. The stresses set up in body panels by reason of the unavoidable flexing of their supporting structure are small if these panels are aluminium. In theory, an aluminium car is a safer one in which to have an accident, and it should be a cheaper accident too, because, when aluminium and steel components of equal strength are compared under impact loading the aluminium one will absorb three times the energy before failure.

These, then, are the general technical points in favour of aluminium alloys, and there follows a brief mention of some of the current lines of development.

Bearings

The aluminium/tin bearing alloys (e.g. Alcoa 750 : 6·5% Sn, 1% Ni, 1% Cu) have already proved their worth in heavy duty operation, and show advantages over white metal in fatigue strength, corrosion resistance, thermal conductivity and anti-friction characteristics: they can be used as solid castings or, in either wrought or cast form, applied to the steel backings of shell bearings. These alloys will be of great help to the engine designer in his attempt to reconcile power requirements with available space and it is to be expected that they will begin to be used within the next year or two.

Bodywork

At the moment, aluminium is losing out in what seems to be a dying market, since cost-consciousness has made those few manufacturers who used it revert to steel. But it is likely that this situation may gradually change because :—

(*i*) The public is becoming more weight conscious; this will mean an increasing demand for lightweight construction as its technical advantages become widely known and as the price of fuel continues to rise.

(*ii*) Severe competition in all markets is once again underlining the importance of mechanical specification, performance and economy. It has already been shown how great a restriction weight can be.

(*iii*) The price differential between steel and aluminium can be expected gradually to narrow if these two metals are considered in the light of (*a*) the relative abundance in which they occur on the earth's surface, and (*b*) the rate of expansion of the motor industry's demand.

(*iv*) There is a possibility that finishes will be required that are only obtainable on aluminium; this refers to the growing trend in the U.S.A. toward textured aluminium panels, which are sometimes anodised.

Technically, there are snags to be expected in any changeover to aluminium, but, once equipment has been installed and techniques are established, assembly costs will probably not be very different from steel. The spot welding of the aluminium/magnesium alloys demands higher currents than for steel, hence bulkier equipment, and closer attention to electrode cleanliness;

nevertheless, both the equipment and the process were brought to a very high level for the Panhard Dyna 54 car.

The lead-loading of seams and of accidental damage is an essential part of car manufacture : it is perfectly feasible on aluminium, using conventional solders, but needs more careful control of temperature if embrittlement is to be avoided. There is some chance, too, that some form of resin-filler could be an economic proposition.

Logically, it should be possible to reduce the pretreatment and painting costs for an aluminium body, if the equivalent life of a steel structure is all that is wanted. However, this point still has to be decided by large scale production, and it is rather doubtful whether much advantage will be found.

The ultimate potential for aluminium could be very great, but, as yet, the economic considerations are against it, and it may be some years before the situation changes appreciably.

Castings

Mention has already been made of the savings which the machining of aluminium can bring and, in the case of castings, this point should be stressed. Unfortunately, this country does not generally follow the American practice of investigating, completely, many prototypes several years before production is contemplated. Under these circumstances, each small team can pick out the material which yields the cheapest finished part. Here the cheapest raw material is more often favoured and less account is taken of costing once the component has entered the machine shop. In defence of this attitude it can, of course, be said that for a given output from, say, an existing automatic transfer machining line, aluminium as a substitute for iron has little to offer. The only savings will be a proportion of the labour costs arising from the handful of men who operate that line. But, and this is where aluminium does come in, if an increase in production is desired and the line is machining iron to capacity, then there are two alternatives :—

(*i*) To change to aluminium and increase the throughput on the same equipment.

(*ii*) To install a new line.

This is a general observation, but it should prove a pertinent one during the next few years.

Additional incentive to the use of aluminium castings is provided by the weight saving factor. The thickness of iron castings for motor use is more often agreed at the minimum the foundry can manage than dictated by considerations of strength or deflection. Aluminium gravity die castings are feasible at even lower general thicknesses, so that a weight saving of 60% or even 70% is often possible. Again, the centre of gravity of the castings embodied in a car is well forward, and any reduction in total casting weight will bring relief to manufacturers who have been forced to adopt undesirable weight distribution ratios in the interest of passenger space.

One particular component, the cylinder block, has received world-wide attention of late. Although alloy crank cases and blocks have been produced in small quantities for many years, the gravity die cast Lancia Aurelia component aroused considerable interest in the U.S.A. The Americans began working on pressure die cast blocks and have now developed a machine capable of producing castings up to about 80 lb. in weight. They have investigated 4, 6 and 8 cylinder blocks and argue that the reduction in machining time and cost, inherent in the use of aluminium pressure die castings, makes these cheaper than sand castings in iron. By choosing pressure die casting as a method, the Americans have limited themselves in choice of alloys and have more or less assumed the necessity of inserted iron cylinder liners : the alloys they envisage are the conventional S.12A, SC84A and SC114A. A die for the 6-cylinder block cost 150,000 dollars, and it is doubtful whether the much lower production rates in this country merit such an expenditure on tooling (quite apart from the absence of suitable die casting machines). On the whole, it seems that gravity die casting is a more attractive proposition for this country, and that, moreover, even this method can compete with the sand casting of iron. Further than this, gravity die casting gives much wider scope in the choice of alloys and the hyper-eutectic aluminium-silicon range may prove suitable for cylinder bores. These alloys, containing finely dispersed free silicon when correctly heat treated, possess Brinell hardnesses approaching those of cast iron, and have already been used, unlinered and untreated, in some quantity for small cylinder barrels.

There will be many snags, associated mainly with the low modulus of elasticity and high thermal expansion, to overcome, and it seems that these two factors are also bothering the Americans. They both lead to noise and wear, but are probably possible to cure by attention to design.

Electrical Systems

With aluminium and copper being so different in weight, yet so similar in price per pound, aluminium can prove to be the more economical, provided :—

(1) That the cost of the installation is dictated by that of the conductor rather than by other factors.

(2) That a cheap end-connection is available.

It is rather doubtful whether aluminium is justified for wiring harnesses, because of these two provisos and because of the multitude of connections which have to be made and which may later become centres of bimetallic corrosion ; but cables of high current-rating, such as starter leads and earth straps, are good applications, since insulation is hardly a factor. Again, the windings of motors, generators and coils provide a fruitful field for aluminium, provided that the implied increase in size of each of these components can be accommodated : the end joints will probably be of the compression type in both these applications.

Radiators

A very great deal has been said and written on this subject recently, because of the incentive to both car designers and aluminium producers. To the motor company, a cost saving is coupled with a reduction of weight in a critical position and the avoidance of a strategic material subject to the control of governments. To the aluminium industry, radiators present a potential of 3,000 or 4,000 tons/year, but there are very big questions still to be answered, and the recent drop in copper prices has probably reduced the immediate interest somewhat.

The case remains sound, for, in a typical installation, 8 lb. of aluminium could replace 15 lb. of copper. Most of the research has been carried out in America, and we have to thank the Korean war for the priority accorded

About 50% of the bright trim on this car was made experimentally in electrolytically brightened and anodised Noral D57S alloy.

to it. Several possible methods of construction have emerged and will be dealt with briefly.

Brazed

By jigging assemblies of pressings in thin gauge NS3 clad with a 7% silicon alloy and dipping in a bath of molten flux, technically-excellent radiators are produced : but costs are very high for varied reasons. Flux losses are a major consideration, since 10% of the radiator volume may be dragout in each dipping operation ; the repair of rejects is extremely difficult ; washing, because it is so essential, is an expensive operation ; and, of course, the first cost of the clad material is high.

Soldered

It remains the ambition of all concerned to put forward a simple method of making soldered aluminium radiators using the equipment which is already installed for the dip, or furnace soldering of copper/brass cores. The problems include the provision of sufficient solder to ensure that each joint is a good one ; the mechanical strength of the radiator during soldering and of the joints after it ; the effective removal of fluxes ; and the resistance to corrosion of the aluminium/solder combinations envisaged. Experience has shown that zinc/aluminium solders are the most suitable, and that the flux should be a solution of zinc chloride in alcohol. Roll-cladding the aluminium with either pure zinc or a 95% Zn/5% Al solder alloy can be of considerable help in overcoming some of the problems, but such a material is neither cheap nor easy to make.

Bimetallic

A half-way-house between the conventional and the all-aluminium radiator is the combination of brass tubes and aluminium fins. The savings in weight and cost are roughly halved (in comparison with the all-aluminium project), but doubts as to water-side corrosion resistance are set aside, and considerable numbers of this type of radiator have been built, using methods substantially akin to those for copper/brass radiators. Tin/lead or zinc/tin solders can be used, though the latter is to be preferred unless zinc-clad finning is employed : once again the zinc chloride in alcohol fluxes have proved to be the most satisfactory, though hydrazine can be used sometimes. At first glance, it seems strange that little corrosion trouble is reported from these bimetallic cores, but such is the case, and evidently the outside of a radiator cannot remain wet for long enough to permit of much action.

Other Types

It would be very convenient indeed if either roll-bonded or impact extruded stock could be used, since each combines water tubes and fins and leaves the tank connections as the only joints to be made. The former material is made by inflating the cavities left by the pattern of stop-off material applied at the interface before two plates are welded under the rolls. Thus, it is essentially restricted to one plane and there can only be two fins per tube. Unfortunately, the efficiency is therefore restricted, since the fins cannot dissipate more heat than their roots can conduct. Impact extruded tubing is a very different product, and can readily be made with the correct fin and root areas. But, once again, it is unsuited to the present concept of radiators because, being an extrusion, all fins are axial and, hence, wrongly placed for the transverse air-flow of the normal radiator. It is possible that either of these materials would prove a sound proposition if the shape or position of a car radiator could be changed to suit.

Trim

Mechanically polished, but unanodised, aluminium has frequently been used in wrought and cast form for trim, especially on French and Italian cars. But some five years ago, Volkswagen fitted mouldings and small pressings in an alloy of super-purity aluminium (99·99%) and magnesium, chemically brightened and anodised. The appearance of these, at least to the layman, is indistinguishable from chromium plate, but in fact they are lighter, cheaper and more durable. Two years later, the Americans began to use alloys based on 99·8% purity metal, often patterned, etched or dyed, but not fully bright.

Mechanical polishing will give a surface of high specular reflectivity, that is a good mirror-image, but of reduced total reflectivity and an indefinable greyness. Electrolytic brightening yields good total and specular reflectivities, and the same is broadly true of chemical brightening (in which current is not required from an external source but is supplied by local electro-chemical action), except that the specular reflectivity is fractionally lower. Almost any aluminium alloy can be brightened to give an excellent finish, but suitability for trim is determined by the alloy's behaviour on anodising, essential if the brightness is to remain unimpaired under corrosive and abrasive conditions. The impurities present in commercial grade aluminium reduce, materially, the transparency of anodic films formed in sulphuric acid, even though these films be very thin (1 or 2 microns) : this effect diminishes with increasing purity until, at 99·99% level, virtually any thickness of film can be applied without impairing brightness. The most suitable film thickness should be determined by the degree of abrasion and corrosion resistance needed and tempered by fitting requirements, since these films are extremely hard and brittle and subject to "craze-cracking" during handling if they are too thick. Actual figures for external trim are hotly debated.

but experience so far indicates that films between 5μ and 10μ will be satisfactory in service. Unfortunately, the price factor militates against the adoption of films in this range, not because of the cost of anodising, but rather on account of the grade of metal. Aluminium of purities up to about 99·9% can be obtained by selecting pig from normal production, and hence carries only a small premium : above this an extra refining operation is necessary and prices rise steeply. Thus, the lower purities imply a big reduction in metal cost but carry with them the penalty of lower brightness which can only be avoided, or rather reduced, by adopting anodic films which may be too thin to give adequate service life.

To improve the mechanical properties of trim materials, magnesium is added and has very little adverse effect on brightness in quantities up to about 3% : in fact, in this country, a content of less than 2% is usual, since one of the electro-brightening processes will not handle, conveniently, a higher magnesium alloy. Noral D57S is one such alloy, containing 1¼% magnesium in 99·99% aluminium : in the half-hard temper, a typical value for the U.T.S. would be 12½ tons/sq. in., against 5½ tons/sq. in. for unalloyed 99·99% aluminium of the same temper.

Alloys of super-purity aluminium with magnesium have been available here in wrought form for some years, and have recently been augmented by a similar range based on lower purities, 99·7% or 99·8% aluminium, but their use on motor vehicles has been comparatively and regrettably small. This state of affairs contrasts sharply with the almost universal adoption of aluminium by the German industry, but can probably be explained by the advanced state of our plating trade and the relative absence of anodising facilities on a large scale.

However, there are signs that this situation is changing, quite logically, so that aluminium trim should be used widely within the next year. Plating is a laborious process, but habitual use over thirty years has established it as the conventional showroom finish for bright parts. It has two competitors, chromium-iron and bright aluminium : of these two, aluminium alone offers equal brightness to that of a plated finish (in fact more, a total reflectivity of over 80%) and gives the added advantage of a small weight saving.

On a volume-for-volume basis the metal cost situation is roughly this :—

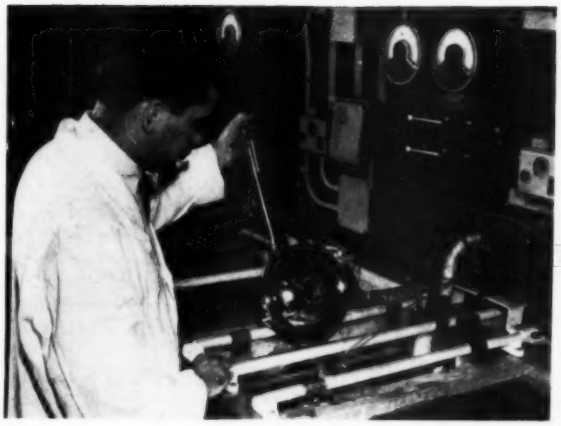
Steel	2 units
Super-purity aluminium ..	5·5 units
Brass	6·3 units
Chromium-iron	10 units

and considering the finishing processes, the mechanical polish for chromium-iron is the cheapest. Second comes brightening and anodising, with plating last.

It is not possible to generalise accurately on total costs, and each component must be worked separately, as there are too many incidental factors which affect the outcome. But in many cases, even super-purity aluminium, apart from its weight and durability advantages, is also seen to be cheapest, so that the lower purity alloys, if their reduced brightness can be tolerated, have a clear field.

Conclusions

In summary, it must be said that, today, the use of aluminium alloys in cars is limited to those fields in which an obvious saving in first cost obtains. Immediate developments are similarly restricted, but it is to be hoped that, before very long, sufficient of the motor car will be made in light alloys to ensure that the user finds it cheaper overall, more durable, safer and more attractive.



Experimental bright-finishing of an aluminium hub cap.

The Nickel Industry in 1957

AFTER many years of nickel shortage for civilian purposes, the combined supply of market and premium price nickel came into close balance with demand in nearly all areas of the world during the last part of 1957. In fact, in the largest market, the United States, the supply exceeded the demand. In that market the year started with demand for civilian purposes much greater than supply and ended with stocks in customers' inventories about 25,000,000 lb. greater than a year ago, and with an accumulation in the hands of the government of a large supply of unsold government nickel diverted from stockpile.

This change was brought about by a record high free world production of nickel, sharply reduced defence demands and the United States Government's endeavour to divert to industry during the year all nickel scheduled for stockpile intake. The last two factors had the effect of greatly increasing the civilian supply in the United States. Some nickel was also released from the United Kingdom's stockpiles for distribution in that country. While free world defence requirements were substantially lower than in 1956, civilian consumption increased to the extent of approximately compensating for the reduced defence consumption.

Indian Iron and Steel Trainees

UNDER the Colombo Plan, twenty-four Indian iron and steel trainees arrived in the United Kingdom last month for between six and twelve months' training in the steel industry under arrangements made by the British Iron and Steel Federation. After their training is completed, they, like the other 300 trainees under this scheme, in which they form the second group, will go back to fill supervisory posts in the new steel works at Durgapur at present under construction by a consortium of British firms. As in the case of all other Colombo Plan trainees in this country, members of this group will be looked after by the British Council during their stay.

Stronger Aluminium Casting Alloys

By F. H. Smith, F.I.M.

Development Officer, ALAR, Ltd.

Demand exists for two types of strong aluminium casting alloy : in one of these proof stress is regarded as more important than ductility and, in the other the reverse is the case. The author reviews the possibilities of alloys of aluminium with copper, magnesium, zinc and magnesium, and silicon and magnesium, and suggests that it should be possible by reducing the iron content of alloy LM 8 to about 0·15%, and appropriate selection of magnesium content and heat-treatment, to produce stronger or, alternatively, tougher castings than those in the current British Standard alloys.

THE search for ever better materials and products is one which continues unceasingly in every industry. In some respects, the development of stronger casting alloys resembles that of a racing machine, in that the achievement of greater strength on the one hand and higher speed on the other, because of their prestige value, may be sufficiently attractive to displace into a secondary position characteristics which, for non-specialist applications, are usually of considerable importance. For a racing car, normal standards of comfort, silence, protection and cost need be subordinate to the primary objectives—speed and performance. Similarly, in the quest for stronger alloys, there is a danger that equally desirable foundry characteristics may become minor considerations compared with the achievement of the superlative tensile properties in specially cast test specimens. Finally, the analogy might be extended to putting these special products into their proper perspective in relation to the wider application of the normal industrial products. Whilst research in the development of both these examples must result in the accumulation of knowledge, some of which can be applied to the improvement of the more commonplace products, the strongest of alloys and the fastest of cars represent a much smaller contribution to the usefulness and prosperity of their respective industries than the glamour and publicity with which they are associated would suggest.

This brief review of established and recently developed strong casting alloys is an examination of the properties of these alloys in relation to the problems and advantages they present to both foundry and user industries.

Requirements of a " Strong " Alloy

First, it is necessary to define what is meant by " strong " alloys, since strength to the user may mean simply tensile strength under static loading, or may refer to toughness or resistance to impact forces. Furthermore, whichever definition is intended, it is the strength of the required casting that is important and not that of a specially cast test piece, although, unfortunately, most of the available data relates to test bars, since these afford the simplest basis for comparison. Finally, the effect of temperature can be a major factor in the actual service strength of a casting, but since piston alloys—to which elevated temperature conditions most commonly apply—represent a special type of application of aluminium alloys, this review is restricted to room temperature properties.

When the stresses in a casting can be determined or calculated with a measure of certainty, the design of the component can properly be based on the elastic limit of the alloy, or approximately the 0·1% proof stress*. The more popularly quoted tensile strength has no significance in design calculations, since it represents a condition in which the elastic deformation which is calculable has been exceeded, and plastic strain which cannot be simply related to the stress has occurred, leaving the casting permanently deformed.

With heat-treated alloys, it is often possible by the appropriate selection of treatment to produce a condition in which the alloy has a high proof stress in relation to its tensile strength, with comparatively low elongation, or, alternatively, higher elongation with correspondingly reduced proof stress. In the light of the above paragraph, it may be difficult at first sight to see why the latter condition should sometimes be preferred. The explanation is simply that in practice most castings are not in fact designed on the basis of an accurate stress analysis; neither are they, for economy in cost and weight, made strong enough to withstand abnormally large overloading. For this reason, an alloy may be selected for a casting because it offers a measure of elongation, and may therefore be expected to deform plastically under excessive overload rather than break, notwithstanding that in either eventuality the casting may be useless for further service. Most such preferences have their origin in aircraft applications, where castings must be produced to minimum weight, but there are certain other industrial uses in which it is preferable that deformation rather than fracture should result from overloading. In general, however, the choice of high-elongation/low-proof-stress instead of high-proof-stress/lower-elongation is an inefficient and uneconomical one, since the lower elastic range of the former necessitates designing to a lower stress level. It is, however, a fact that, whether completely justifiable or not, a demand exists for both types of strong alloy, namely (*a*) high-proof/tensile-strength, and (*b*) tough or able to absorb energy by plastic deformation.

On this basis, it is desirable to examine (1) the extent to which such alloys are at present used ; (2) the extent to which their use is affected by other characteristics either in the foundry or in service ; and (3) whether the present alloys can be improved, or whether better alloys are likely to become available in the foreseeable future.

Five alloys in B.S.1490—Aluminium Ingots and Castings for General Engineering Uses—may be con-

* For convenience in this review the 0·1% proof stress is assumed to correspond approximately to the elastic limit.

sidered as high strength alloys and have the typical properties set out in Table I, measured on separately cast test bars produced to B.S.1490, i.e. cylindrical bars 1 in. in diameter, machined to provide a 2 in. gauge length of 0·564 in. diameter.

The production of these alloys in the U.K., according to the statistics compiled by a group of ingot makers, probably represented in all, in 1956, little more than 3% of the total of aluminium casting alloys, and of this minor role LM8 and LM10 each contributed over one third. It is likely that in 1957 the use of the alloy LM8 will have increased a little and LM10, for reasons to be discussed later, decreased. These figures provide a measure of the extent to which aluminium alloy castings are used for highly stressed components, and puts the strong alloys into their proper perspective in relation to the aluminium foundry industry production as a whole. Although, however, their contribution is small it is not insignificant, and might well be expected to increase if stronger and better alloys are developed.

Of the five strong alloys, two—LM10 and LM11—may be described as tough alloys, and the ability of castings of either to withstand very severe deformation without breaking has been demonstrated many times; it might consequently be inferred that these compositions would satisfy the demands for this type of alloy. On analysis this proves not to be so, for, in addition to the slight disadvantage of a rather lower proof stress than the stronger alloys, LM10 and LM11 have other characteristics which tend to limit their use.

TABLE I.—TYPICAL MECHANICAL PROPERTIES OF HIGH STRENGTH CASTING ALLOYS.

Alloy	Sand Cast			Chill Cast		
	Tensile Strength (tons/sq. in.)	0·1% Proof Stress (tons/sq. in.)	Elongation on 2 in. (%)	Tensile Strength (tons/sq. in.)	0·1% Proof Stress (tons/sq. in.)	Elongation on 2 in. (%)
LM8-WP	16	14	1	19	14	2·5
LM9-WP	16·5	14	—	20	17	1
LM10-W	19	10	12	22	11	18
LM11-WP	19	12	5	22	12	10
LM16-WP	16	14	1	19	16	2

Aluminium-Copper Alloys

The 4–5% copper alloy LM11 depends for its high strength and ductility upon the maximum solution of the copper constituent on heat-treatment, and freedom from the embrittling effect of grain boundary constituents. Ideally, it is a single phase alloy, but practical economics demand the acceptance of small iron and silicon contents (0·25% max. each), which in practice are commonly of the order of 0·15% each. If the iron and silicon were further reduced and the copper range raised slightly (since 5% does not represent the maximum solubility of copper in aluminium), it should be possible with a suitable heat-treatment to improve significantly the strength and ductility of the alloy. Such a prospect is of little more than theoretical interest, since the practical problem of maintaining extremely low maximum iron and silicon contents would demand the punctilious attention of a foundry confined to the casting of one alloy and using in all probability special tools and refractories. Hardy[1] has shown that enhanced proof and tensile stresses can be achieved by the addition of a small amount of cadmium to the aluminium-copper alloy, but that this is accompanied by a marked decrease in elongation in the fully heat-treated alloy. Such an addition would consequently not assist in attaining the objective, namely a strong, shock-resistant alloy. It should also be mentioned in passing that there exists a further specification for the 4–5% copper alloy—D.T.D.361—in which the artificial ageing conditions are selected to produce a tensile strength some 3 tons/sq. in. higher than that shown in Table I for LM11-WP, and having nearly twice the proof stress of the latter.

It is, however, unlikely that my attempt to improve the mechanical properties of the LM11 alloy would be worth consideration without a major composition change to improve also the foundry characteristics. The tendency of the alloy to hot-tearing restricts its use mainly to sand castings which are not too complex in shape, and to the simplest of gravity die castings. Furthermore, the problem of obtaining castings of varying section free from shrinkage porosity is additionally acute in a long freezing range alloy of this type, as has been found by Ruddle[2]. For this reason, it is difficult to reproduce the order of tensile value shown in Table I in castings so shaped that optimum temperature gradients and directional solidification cannot be achieved.

The casting characteristics of the binary alloy could undoubtedly be very greatly improved. According to Jennings *et al.*,[3] additions of 2·5–3% silicon reduced the susceptibility of the 4·5% copper alloy to hot-tearing in their ring test by about four-fifths.

A reduction in tendency of the alloy to tear during solidification in chill and intricate sand moulds would undoubtedly lead to a substantial increase in the use of the alloy if the present mechanical properties could be maintained. There is, in addition to the results reported by Jennings, practical experience of the satisfactory foundry characteristics of a 4·5% copper–2·5% silicon alloy, since, in the U.S.A., the resistance to hot-tearing of the A.S.T.M. alloy CS42A is thought adequate to justify the alloy being specified for permanent mould castings.

From the constitution of the alloy, it would be expected that an increase in the silicon content from a maximum of 0·25% to 2·5% would have some adverse effect on its tensile properties, but if this were small it might be outweighed by an improvement in the actual properties of castings resulting from the improved castability. In fact, it appears from recent tests made by the B.N.F.M.R.A. that, whilst such an addition of silicon does not significantly affect the proof stress of the fully heat-treated alloy, the elongation, and to a smaller extent the tensile strength, are so reduced as to exclude this modification in composition as a practical solution. Although in practice the alloy LM11 does produce castings of excellent mechanical properties for a limited range of comparatively simple castings, it seems unlikely

TABLE II.—CHEMICAL COMPOSITION OF HIGH STRENGTH ALLOYS.

Alloy	Cu%	Mg%	Si%	Fe%	Mn%	Ni%	Zn%	Pb%	Sn%	Ti%	Al%
LM8.. ..	0·1	0·3–0·8	3·5–6·0	0·6	0·5	0·1	0·1	0·1	0·05	0·2	Rem.
LM9.. ..	0·1	0·2–0·6	10·0–13·0	0·6	0·3–0·7	0·1	0·1	0·1	0·05	0·2	Rem.
LM10 ..	0·1	9·5–11·0	0·25	0·35	0·10	0·10	0·10	0·05	0·05	0·2	Rem.
LM11 ..	4·0–5·0	0·10	0·25	0·25	0·10	0·10	0·10	0·05	0·05	0·05–0·30	Rem.
LM16 ..	1·0–1·5	0·4–0·6	4·5–5·5	0·6	0·5	0·25	0·1	0·05	0·05	—	Rem.

Single figures are maxima.

at the present time that it can be improved in characteristics and properties to a degree which would lead to its extended application.

Aluminium-Magnesium Alloys

The other alloy in Table I which appears to meet the requirement of a strong, impact-resistant material is the aluminium–10% magnesium alloy, LM10. This alloy has a useful combination of strength and ductility, although its elastic limit is a little low. It has better resistance to hot-tearing and to corrosion that has the alternative LM11 alloy, and has in fact in the past been more widely used.

Nevertheless, it presents greater difficulty in the foundry than do most aluminium alloys, because of its tendency to dross formation and to gas absorption, and because of its reaction with the moisture in moulding sands. Techniques[4] have been developed and are regularly practised to minimise these effects. Similarly, grain refinement has been shown[5] to reduce the harmful effect of microporosity to which this alloy is prone in poorly fed castings. Jay and Cibula[6] have demonstrated that the layer formation which porosity may take in underfed castings, and which has a marked deleterious effect on the tensile properties of castings, is significantly reduced as the magnesium content approaches the maximum permitted by the LM10 specification. The same article draws attention to the segregation which may occur in castings as a result of the flow of magnesium-rich liquid from feeding heads. This possible difference in composition between feeders and castings demands greater analytical control in the foundry than is necessary with most alloys, to ensure that the remelting of runners and risers does not subsequently produce castings with less than the optimum magnesium content, or, more seriously, less than the specification minimum.

Like LM11, the aluminium-magnesium alloy LM10 is, after heat-treatment, essentially a single phase alloy, and only small amounts of impurity elements are permitted to be present. Of these, iron from melting tools and silicon from other foundry alloys are the most likely contaminants, and rigorous care must be taken to make certain that they are excluded. Silicon in particular, by the formation of the constituent Mg_2Si which, when present, occurs at the grain boundaries, has a most deleterious effect[7] on the tensile properties of the alloy.

Considerable quantities of castings in LM10 alloy have been successfully produced for many years despite the foundry problems referred to above, but it is apparent that the use of the alloy must in practice be limited to those foundries which have the necessarily high degree of technical control. Ideally, LM10 castings should be produced in a foundry reserved exclusively for this purpose, and the inhibited sand which has a harmful effect on castings in other alloys, e.g. LM6, must be very carefully segregated.

It is known that castings in LM10-W alloy are liable (as are many other alloys) to suffer from stress corrosion if exposed to corrosive conditions under high test loads. It is also known that a little ageing of the solution-treated alloy occurs at ordinary room temperatures, and that the rate increases with rising temperature. Since ageing reduces the resistance of the alloy to stress corrosion, it is advisable in the present state of knowledge to restrict the use of LM10-W castings, where these are highly stressed under conditions known to be adverse, to applications at normal atmospheric temperatures. There is no conclusive evidence that castings in LM10-W alloy have failed in service as a result of stress corrosion when used under normally acceptable conditions of loading, but it would extend the range of application of LM10-W castings if the factors affecting stress corrosion were more accurately established, and if the progress of age-hardening, in relation to time, temperature and composition, were determined.

Investigation aimed at improving the LM10 type of alloy is mainly confined to a research recently started by the B.N.F.M.R.A. to study the stress corrosion of this class of alloy, and it remains to be seen whether this work, in addition to providing the information referred to in the previous paragraph, will lead to changes in the composition of the alloy which would still further reduce the problems of the foundry.

A report on some work carried out by the Battelle Memorial Institute[8] has recently been made available by the U.S. Department of Commerce. In this, the authors claim that an alloy containing 9·5% magnesium has a number of advantages over the higher end of the range of 9·5–10·6% allowed in the American alloy 220, and suggest that it should be possible to obtain the minimum tensile properties required for this alloy with even lower magnesium contents. The benefits claimed for the 9–9·5% magnesium alloy include reduced difficulties due to porosity, metal mould reaction and as-cast brittleness, and superior tensile properties compared with those expected from the U.S. alloy 220. (Apart from the slightly shorter magnesium range, this alloy is practically identical to LM10 in composition).

None of the first three of these claims is based on experimental evidence; the first is at variance with the British work referred to above[4, 5, 6] and the reduction in the second and third would probably be only of a minor order. The tensile properties found by the Battelle investigators, of which the following may be considered typical:

Tensile Strength	24 tons/sq. in.
0·2% Proof Stress	12 tons/sq. in.
Elongation	22%

whilst higher than those usually quoted for the 220 alloy, are obtainable with LM10-W sand cast test bars produced under closely controlled conditions.

For the other claims made there may be greater justification. These are: that with 9–9·5% magnesium, room temperature ageing, whilst increasing the proof strength, does not at the same time reduce the elongation, whereas for the few test specimens containing 10·5% magnesium which were aged up to 70 days, an increase of approximately 2 tons sq. in. in proof strength was accompanied by a loss of 2·5% in elongation. On the basis of this evidence, it is suggested that the lower-magnesium alloy would have a reduced susceptibility to stress corrosion, but again there is no confirmatory experimental evidence.

A further finding of the Battelle investigations may lead to a reduction in the number of casts of LM10 alloy having rather low mechanical properties with no apparent explanation. A comparison of melts producing test bars with high mechanical properties with those giving low properties (grain size, porosity and other factors being approximately the same) revealed that the differ-

ence was associated with the titanium content. All melts containing 0·1% or more titanium had lower ductility and tensile strengths than those containing 0·01–0·05% titanium; approximately 0·005% boron was present in all melts. Examination of test bars containing the higher amounts of titanium revealed the presence of a titanium-rich constituent, tentatively identified as $TiAl_3$, in the grain boundaries. Since iron-rich and Mg_2Si constituents occurring at the grain boundaries are known to affect adversely strength and ductility in the alloy, it is concluded that these titanium-rich constituents have a similar effect. If this can be confirmed, it will provide a further argument for adopting the grain refining method recommended by Cibula[9] (0·01% titanium with 0·005% boron), which should result in a reduction of the scatter of tensile test properties.

Aluminium-Magnesium-Zinc Alloys

As part of their investigations to produce an improved high-strength aluminium-magnesium alloy, the Battelle team have examined the influence of the addition of zinc as an alloying element. There are a number of aluminium casting alloys in use in the U.S.A. in which zinc and magnesium are the main alloying elements, e.g. ZG32A, ZG42A, ZG61A/B, but these are essentially different in that they are high-zinc low-magnesium compositions, and are used in the naturally aged condition. Furthermore, they do not provide the combination of high strength and ductility obtainable from LM10 or the U.S. alloy 220 (G10A). Similarly, the aluminium-zinc-magnesium alloy D.T.D. 5008 (40E), whilst also avoiding the need for solution treatment, does not develop tensile properties comparable with LM10.

The Battelle investigators have developed an aluminium-magnesium-zinc alloy based on aluminium of 99·75% purity, and containing 6·5–7·5% magnesium and 2·5–3·0% zinc with a specified sum and ratio for these two elements. The minimum tensile properties claimed for the solution treated and artificially aged condition are for sand castings:

Tensile Strength	21 tons/sq. in.
0·2% Proof Stress	16 tons/sq. in.
Elongation on 2 in.	8%

Typical tensile properties of sand cast test bars obtainable with different conditions of precipitation treatment are reported as:

Tensile Strength (tons/sq. in.)	0·2% Proof Stress (tons/sq. in.)	Elongation (%)
24	17	8
29	22	3
26	19	1·5

Although the ductility is not as good as that of the LM10 alloy, the combination of proof stress and elongation shown in the first line is better, and should be adequate for almost every application for which castings are likely to be used; furthermore, the alloy has the advantage that a range of properties is available by varying the heat-treatment.

In the foundry, the alloy has some of the disadvantages of the aluminium–10% magnesium alloy, in that it is of the same order of purity and requires special attention to prevent loss of characteristics, through iron and silicon pick-up or by other contamination; it also has a similar tendency towards brittleness before solution heat-treatment. The authors do not comment in detail on the gas absorption, degassing and metal-mould reaction by comparison with the aluminium–10%-magnesium alloy, but approximately the same treatment and inhibition were employed. It might be expected that for the ternary alloy the foundry problems would be a little eased.

Some aluminium-magnesium-zinc compositions are known to age at room temperature to a condition of very low ductility. An accelerated test at 115° C. for 48 hours following precipitation treatment, however, indicates that only a small amount of age-hardening is likely to occur in the service life of castings employed at room temperature.

The corrosion tests which have been carried out are inconclusive for a number of reasons, but it is of interest to note that the attack from repeated immersion in 3% sodium chloride solution took the form of pitting, and not intergranular penetration. It is also stated in the report that ageing does not seriously impair the corrosion resistance, but it does not appear from the data available that this has been comprehensively investigated.

It is unfortunate, since resistance to stress corrosion is likely to be a major consideration in assessing the possible substitution of the aluminium–10% magnesium alloy by the Battelle alloy, that the tests carried out to compare the two alloys were of such a limited scope. The results do no more than suggest that the order of stress corrosion under one set of test conditions is similar for the aluminium–10% magnesium and the aluminium-magnesium-zinc alloy. The need for further data, in particular in relation to the condition of ageing of the latter alloy, is recognised by the authors.

Aluminium-Silicon-Magnesium Alloys

The remaining three alloys in Tables I and II are considered together under this heading, since, despite the presence of a third alloying element—copper—LM16 is similar in many of its characteristics to LM8.

The alloys LM8 and LM9 are both aluminium-silicon alloys containing Mg_2Si, and their properties are sufficiently similar to raise doubts about the need for the retention of both in B.S.1490. Whilst some benefits might be afforded by the shorter freezing range and slightly superior mould filling capacity of the higher silicon alloy, LM9 has the disadvantage in the foundry that it requires to be treated by the modification process with all its attendant difficulties. Furthermore, it has a pronounced tendency to piping in underfed sections of castings. Finally, its high silicon content makes it inferior to LM8 in machinability.

For these reasons, and in the interest of simplicity, no further reference will be made to LM9 alloy, but much of the comment on LM8 may be assumed to apply equally to the former alloy.

LM8-WP and LM16-WP have higher proof strengths (see Table I) than the two alloys discussed earlier, namely LM10-W and LM11-WP, and would be obvious alternative choices for high strength castings accurately designed on the basis of elastic limits. The fact that both have much lower ductility than LM10-W and LM11-WP is, as argued earlier, irrelevant. Since all are high strength alloys, it is of interest to compare their casting characteristics—important factors in determining the selection of an alloy.

The special problems associated with LM10 and LM11 in the foundry have been briefly described. None of these

difficulties arises in the melting or casting of LM8 or LM16. The latter alloys may be cast with equal ease in either sand or chill moulds; they are free flowing alloys; are not subject to hot-tearing; are far less sensitive to the effects of gas absorption, casting temperature, grain size, casting mass and variations in composition; and are, in short, excellent casting alloys in almost every respect. One of the few advantages which can be claimed for the two more ductile alloys is ease of machinability. Applications demanding strong, corrosion resistant castings, for which LM10-W is sometimes recommended, would in most cases be better and more readily satisfied by LM8-WP.

In view of the attractive foundry characteristics of the aluminium-silicon-magnesium and aluminium-silicon-magnesium-copper alloys, it is of interest to review recent developments to see whether even higher tensile properties are obtainable, and in the light of the foundry problems associated with the alloys LM10 and LM11, to examine the practicability of developing similar alloys which would satisfy the demand for strong alloys with comparable ductility, but would have improved castability.

Several significant steps[10, 11, 12, 13] in this direction have been reported within the last two years. This work and that referred to later has all been carried out on the American alloys 355 and 356, or essentially similar alloys. The A.S.T.M. Specifications for these two alloys, respectively SC51A and SG70A, have the following composition requirements (single figures are maxima):

	Cu%	Mg%	Si%	Fe%
SC51A (355)	1·0–1·5	0·45–0·6	4·5–5·5	0·6
SG70A (356)	0·25	0·25–0·40	6·5–7·5	0·50
	Mn%	Zn%	Cr%	Ti%
SC51A (355)	0·50	0·35	0·25	0·25
SG70A (356)	0·35	0·35	—	0·25

The alloys 355 and LM16 are practically identical, but 356 has a rather higher silicon content than LM8. Despite this difference in silicon, it is thought that the results of the American investigation on 356 alloy would be largely applicable also to the British alloy.

The high silicon alloys such as LM6 (10–13% silicon) benefit very considerably from sodium modification treatment, and it might be expected that similar advantage would be gained by the application of this process to the alloy 356. Harris *et al.*[14] have made a study of the effect of sodium modification on the age-hardening characteristics and tensile properties of 356 alloy. Examination of microstructures showed that the treatment produced a modification of the normal plate-like form of silicon to a rounded globular form but, despite this transformation, which might well be beneficial in other ways, the authors found that sodium treatment has no effect on the normally measured tensile properties, unless the magnesium content is below 0·2%, i.e. less than the specified minimum.

Harris *et al.* also refer to the effect on the tensile properties of the interval between quenching from solution treatment and subsequent precipitation treatment. Quadt,[15] who studied this effect, has shown that for both the alloys 355 and 356 elongation may be improved by about one third at the expense of proof and tensile strength by ageing castings for 24 hours at room temperature before precipitation. By artificially ageing immediately after quenching, higher strength and hardness are obtainable at the expense of elongation. Whilst not providing a means of improving the

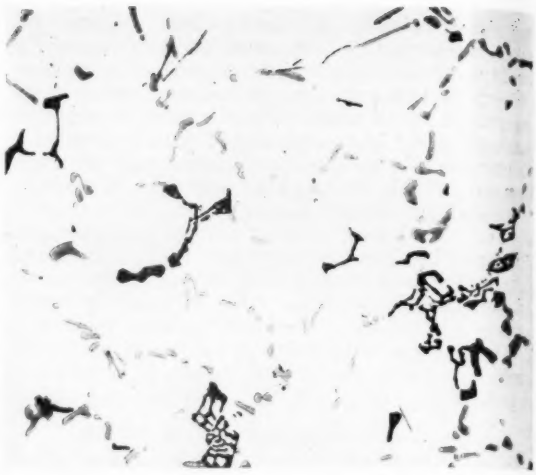


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Fig. 1.—Microstructure of LM8 alloy. ×250

combination of strength and ductility, these results suggest that it should be possible, to some extent, to adjust the tensile properties of LM8 and LM16 castings according to particular requirements by variation in heat-treatment technique.

By far the most effective improvement in the mechanical properties of the alloys 355 and 356 has been achieved by a slight modification to the chemical composition. Attention has earlier been called to the harmful effect of iron on the high strength aluminium-copper, aluminium-magnesium, and aluminium-magnesium-zinc alloys, and it has been shown by Archer and Kempf[16] that iron has a deleterious effect on the ductility of aluminium-silicon-magnesium alloys. Fig. 1 shows a typical cast structure of a specimen of LM8 alloy in which the iron-rich constituents (dark) can be seen in the form of "Chinese script," needles, and sometimes a more rounded shape, all very largely associated with the grain boundaries. The sample illustrated contains 0·6% iron, and it is not surprising in view of the distribution of the rather brittle iron-rich constituent that a reduction in the iron content is found to result in an increase in the ductility of the alloy.

Lemon and Hunsicker[10] have shown that by reducing the iron content of 355 and 356 alloys from the nominal 0·6% to 0·2%, it is possible to double the elongation. Not only is this of merit in making available a more ductile alloy but, what is probably more important, it permits a more intensive precipitation treatment to produce a higher strength with still a fair measure of ductility. With the normal, but higher, iron content, such a treatment would produce a condition of very low elongation. The figures in Table III illustrate the effect of the iron content and of extended precipitation treatment time on the alloys 355 and 356. The condition T6 represents normal solution treatment followed by artificial ageing, and T61–further precipitation treatment. The values are taken from the paper by Lemon and Hunsicker and relate to cast-to-size chill bars, and are not consequently strictly comparable with results to be expected under British tensile testing conditions. The copper-containing alloy 355 is shown to give considerably higher tensile and proof strengths but lower ductility than the copper-free alloy 356.

TABLE III.—EFFECT OF IRON CONTENT AND EXTENDED PRECIPITATION TREATMENT ON THE MECHANICAL PROPERTIES OF ALLOYS 355 AND 356. (CHILL CAST BARS)

Alloy	Tensile Strength (tons./sq. in.)	0·2% Proof Stress (tons/sq. in.)	Elongation on 2 in. (%)
356-T6 (0·6% Fe)	18	12	5
356-T6 (0·2% Fe)	16	10	15
356-T61 (0·2% Fe)	19	13	10
355-T62 (0·6% Fe)	20	18	2
355-T62 (0·2% Fe)	24	20	4
355-T61 (0·2% Fe)	20	15	6

DeRoss[11] has further explored the effect of precipitation conditions following solution treatment of the alloy 356 with normal and low-iron contents. He has also taken advantage of the higher ductility of the lower-iron alloy by increasing the magnesium content, and thus achieving a higher tensile strength whilst still retaining an acceptable measure of elongation. Of the wide range of tensile properties reported by DeRoss, those shown in Table IV are typical of the optimum precipitation conditions. It is evident from these results that there are, in fact, substantial benefits to be gained in tensile properties by a reduction in the iron content of this alloy, and by an increase in the magnesium content where maximum strength is required.

Confirmation that the improved properties, at least for the low-iron version of the 355 alloy, are obtainable in specimens machined from castings solidifying over a wide range of freezing times, as well as in standard test bars, is provided by Owen and Marsh.[17] These investigators made tests on specimens cut from a 12 in. sand cast plate, $\frac{3}{4}$-in. in thickness, over which the time of freezing varied from 40 seconds to 15 minutes. They found a consistent superiority of the lower-iron (0·12%) 355 alloy over the standard alloy (0·4%) over the whole range of solidification rates. Their results confirm that an improvement in elongation up to 100% is obtainable with the higher purity alloy, and that if the castings are heat-treated to give equal ductility for both versions of the alloy, the lower-iron alloy has a superiority in yield and tensile strength of 25–30% over the normal alloy.

Owen and Marsh also provide data to illustrate the significant increases in tensile and yield strengths (approximately 2 and 1 ton./sq. in. respectively) which result from quenching from solution treatment in water at 60° C. instead of the usual 100° C. Opportunity to take advantage of this effect may occur occasionally, but it is only of limited interest, since quenching-water temperatures are usually dictated by the need to avoid internal stresses in the castings, and so depend on the shape and complexity of the part. It should be mentioned that other strong alloys are similarly affected by a reduction in the temperature of the quenching water, and that this method of increasing the tensile properties of strong alloys cannot be claimed to apply exclusively to the aluminium-silicon-magnesium (copper) type. On the other hand, it is commonly stated that the more rapid cooling of LM10 alloy castings, which results from quenching in water instead of hot oil, renders the castings more susceptible to stress corrosion, but the reviewer knows of no published evidence to support this.

The most recent claim to the development of higher tensile properties in the aluminium-silicon-magnesium casting alloys is made by North American Aviation, whose data[13] for their alloy designated 42B include the following :

	Sand Cast	Chill Cast
Tensile Strength (tons/sq. in.)	20	22
0·2% Proof Stress (tons/sq. in.)	16	20
Elongation on 2 in. (%)	5·0	6·0

TABLE IV.—EFFECT OF IRON AND MAGNESIUM CONTENTS ON MECHANICAL PROPERTIES OF ALLOYS 355 AND 356.

Alloy	Sand Cast			Chill Cast		
	Tensile Strength (tons/sq. in.)	0·2% Proof Stress (tons/sq. in.)	Elongation on 2 in. (%)	Tensile Strength (tons/sq. in.)	0·2% Proof Stress (tons/sq. in.)	Elongation on 2 in. (%)
356 (0·4%Fe, 0·3%Mg)	16	13	3·5	18	15	6·0
356 (0·12%Fe, 0·3%Mg)	18	15	8·0	19	14	11·0
356 (0·1%Fe, 0·6%Mg)	21	20	2·0	21	18	3·0

No details are as yet available of the composition of the alloy 42B, but the makers describe it as a magnesium silicide alloy and mention additions of sodium and beryllium ; they also state that it is not a high purity alloy. The presence of sodium, if the amount is in fact significant, would suggest a moderately high silicon content, since Harris and his colleagues[14] found that sodium modification had no beneficial effect on the tensile properties of the 356 (7% silicon) alloy. The claim that 42B has higher fluidity than 356 suggests that the alloy may be of the LM9 type, although the elongation values are higher than are normally obtainable with LM9-WP.

In assessing the significance of the recently published developments of the aluminium-silicon-magnesium (copper) types of alloy, the properties claimed for 42B must be noted, but the relative importance of this alloy cannot be determined until further information is available. The other developments reviewed suggest that the time is opportune for a reassessment of the British alloys available for the production of strong castings. Comparison of the properties in Table I with those in Tables III and IV must be made guardedly, not only because of the difference in test specimens, but because the British values are typical of average compositions and do not represent the properties which are obtainable from extremes of the composition ranges, particularly for LM8 and LM16. Nevertheless, it is apparent that the alloy 356, with an iron content of the order of 0·15% and magnesium contents of 0·3% and 0·6%, is capable—with appropriate heat-treatment—of giving a range of tensile properties wider than that at present offered by the five standard British alloys. Even allowing for the difference between 0·1 and 0·2% proof stress measurement, none of the alloys in Table I has a proof stress approaching the 20 tons/sq. in. shown for sand castings in the last line in Table IV (together with a fair measure of elongation). Similarly, the properties shown in the second line of Table IV offer, in the reviewer's opinion, a more useful combination of proof strength and elongation than that of either LM10 or LM11 in Table I, since the higher elastic limit of the 356 alloy would allow the designer to work at a higher stress level than would be possible with LM10 or LM11, and castings in the 356 alloy would still have ample ductility to provide a safety margin against fracture in the event of severe overloading. An even higher elastic limit might be obtainable, by analogy from the data in Tables III and IV, by increasing the magnesium content of the low-iron version of the alloy 355. This should prove useful for castings accurately designed to the stress requirements of the application and not relying on ductility to restrict failure to permanent deformation, rather than fracture, in the event of overloading.

The practicability of substituting a modified LM8 alloy, assuming the improved tensile properties of the special 356 alloy to be obtainable, for castings at present employing the alloys LM10 or LM11 is increased when

the relative foundry characteristics are taken into consideration. With one exception, all the particular difficulties encountered in the melting and casting of the alloys LM10 and LM11 are avoided by using LM8, and there is, furthermore, evidence that a higher proportion of " test bar tensile properties " over a wide range of thickness of casting is obtainable with LM8.[18] The problem of maintaining the iron content of the alloy at the necessary low maximum, whilst admittedly requiring special care in the foundry, is one which has also to be overcome whenever the alloys LM10 and LM11 are cast.

There is no evidence, so far as the reviewer is aware, that alloys of the LM8 type are dangerously susceptible to stress corrosion, although it would be desirable to confirm this for the more fully artificially aged condition. Furthermore, compared with the evidence provided earlier,[8] the fully heat-treated LM8 alloy should give no anxiety on the grounds of instability. Finally, under lightly stressed conditions, LM8-WP castings would be as resistant to corrosion as LM10-W in most media, and superior to LM11-WP.

The only advantage which the alloys LM10 and LM11 have over LM8 is ease of machining. The former are two of the most readily machined casting alloys, whereas LM8 suffers from the disadvantage that, like all silicon-containing alloys, it gives rise to greater tool wear. However, cast LM8 alloy is regularly machined, using the appropriate tools and technique, to give an excellent standard of finish, and the difference between it and the alloys LM10 and LM11 is not of very great significance in practice.

Summary and Conclusion

A review of the properties and characteristics of the stronger aluminium casting alloys suggests that it should be possible, by limiting the iron content of the aluminium-silicon-magnesium alloy LM8 to approximately 0·15%, and by appropriate selection of magnesium content and heat-treatment, to produce castings with tensile properties in excess of the present range offered by the current British Standard alloys. Not only should such an alloy make possible stronger, or alternatively " tougher " castings, but the production of the latter would be facilitated by the avoidance of the foundry difficulties associated with the two alloys LM10 and LM11. Furthermore, the use of the low-iron version of the LM8 alloy would overcome the fears—whether these have any foundation in practice or not—of the stability and resistance to stress corrosion of castings to the present LM10-W requirements. The cost of a higher purity LM8 alloy should not be greater than that of the alloys LM10 or LM11, and the advantages appear to be sufficiently attractive to justify a thorough investigation of the properties and characteristics of such an alloy. The goal could be the replacement of the present five strong alloys by a single one—an LM8 capable, by adjustment of composition and heat-treatment, of giving a very wide range of tensile properties. A similar investigation of the alloy LM16 might well produce an alloy of even higher elastic limit and hardness, although such a development would reduce the advantages of the simplicity of a single strong alloy.

Investigations aimed at improving certain of the characteristics of the aluminium–10% magnesium alloy by a reduction in the magnesium content and by the addition of zinc as an alloying element have been reviewed, but these modifications do not significantly improve the order of castability of the alloy, and are consequently of secondary importance in the light of the potentialities of the aluminium-silicon-magnesium alloy.

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Greater Use of Industrial Instruments

THE number of small, inefficient, hand-run plants would become gradually fewer ; and as firms became larger and amalgamations occurred, the drive for industrial instruments and their better use would go forward, said Mr. S. P. Chambers, C.B., C.I.E., Senior Deputy Chairman of Imperial Chemical Industries, Ltd., at the Annual Luncheon of B.I.M.C.A.M. (British Industrial Measuring & Control Apparatus Manufacturers' Association) in London on 7th January. He mentioned Sir Alexander Fleck's report that the Windscale incident would never have happened if there had been better understanding of the instruments and if they had been more conveniently placed. These instruments were of little value unless adequately trained staff were available to install and use them properly.

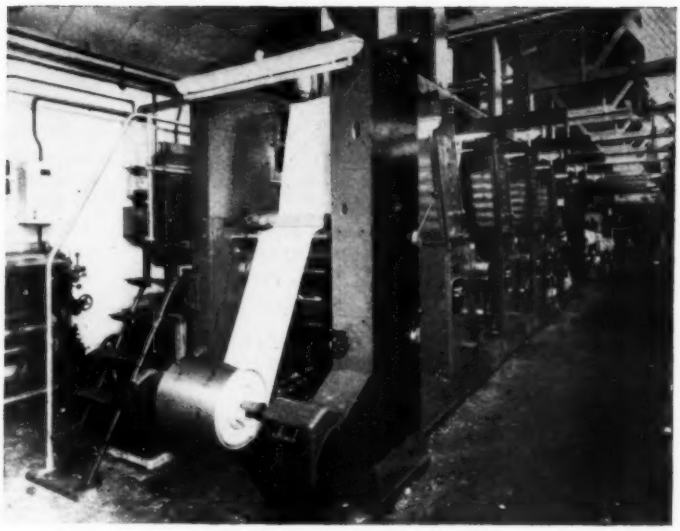
Mr. E. W. Wilson, Chairman of B.I.M.C.A.M., referred to the export record of the Association for 1957, in which it was expected that exports would exceed £15 million out of a total turnover of £35 million. He stressed that home trade was the basis of export sales, and expressed the hope that this basis would expand with the anticipated increase of the export market when the European Free Trade Area came into being.

Asian Iron and Steel Experts

DURING their recent tour of iron and steel works in the United Kingdom, members of the 17-strong ECAFE (Economic Commission for Asia and the Far East) group of iron and steel experts were entertained to lunch by the Chairman and Directors of Metallurgical Equipment Export Co., Ltd., the British consortium of steel works plant manufacturers. In his address of welcome, Mr. D. F. Campbell, Chairman of the Company, emphasised the willingness of British steelmakers and plant manufacturers to share their experience and knowledge with the Asian countries. Replying on behalf of the ECAFE group, Mr. B. N. Gupta expressed their appreciation of the free and frank interchange of ideas and opinions on modern techniques which members had found possible during their visit to Britain. British experts, he said, would be welcomed by members of the group in their respective countries.

The Production and Conversion of Aluminium Foil

By J. R. Green,
L.I.M., M. Inst. Pkg.
Chief Chemist, Star Aluminium Co., Ltd.



Foil printing by rotagravure.

If it were all made from home-produced virgin metal, the United Kingdom's production of aluminium foil would account for more than half the output of British reduction plants. This is a measure of the widespread use of this material, and in this article the author outlines the properties which give it such a wide appeal, and briefly describes its production and applications.

UNITED KINGDOM production of aluminium foil is currently running at the rate of just over 20,000 tons annually—quite a jump in ten years from the 6,000 tons or so in 1947. The bulk of this production is used in one way or another by the packaging industry, where the useful properties, attractive appearance and versatility of aluminium foil are extremely valuable. Among other rapidly growing applications are thermal insulation and electrical equipment.

Standards

In general, foil is made from aluminium conforming to B.S. 1470 SIC, which has a minimum aluminium content of 99%, with a limitation on impurities of

Copper not more than	0·10%
Silicon not more than	0·5%
Iron not more than	0·7%
Manganese not more than ..	0·1%

There are exceptions, one example being electrolytic condensers, where high purity metal containing 99·8% or 99·99% aluminium is required.

The definition of foil—in terms of maximum thickness—varies in different countries. In the United Kingdom it is considered to be foil up to a thickness of 0·15 mm.: in France the upper limit is 0·2 mm., in Italy 0·05 mm., and in Sweden 0·04 mm. Although the metric system is generally used for expressing gauge, in the United States it is frequently stated in inches, the maximum thickness being 0·006 in. Because of the possible use of both the English and metric systems, the figures given in Table I should be useful in converting one to the other.

TABLE I.—CONVERSION FROM METRIC TO ENGLISH SYSTEM

Thickness		Area Covered by Unit Weight	
mm.	in.	sq. in./lb.	sq. m./kg.
0·004	0·000146	64,800	92·50
0·006	0·000225	45,400	61·60
0·009	0·000335	29,000	41·20
0·010	0·000339	26,000	36·90
0·012	0·000447	21,700	30·80
0·015	0·000559	17,500	24·80
0·020	0·000679	13,000	18·50
0·040	0·001157	6,500	9·25
0·065	0·002256	4,010	5·67
0·070	0·002276	3,710	5·27
0·100	0·003394	2,600	3·69
0·150	0·005590	1,730	2·46

Foil Production

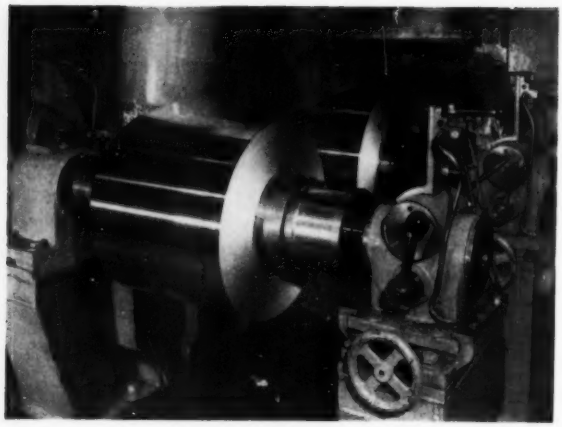
Foil Stock

The casting of sound homogeneous billets and slabs from melted aluminium ingots is the first stage in the preparation of foil stock, which is normally 0·45–0·70 mm. thick strip. This is usually rolled from a continuously cast slab, which is reduced 90% by hot rolling and then cold rolled down to gauge. At this stage the strip is annealed to the fully soft state. It is most important that such fluctuations of gauge as occur in the length of the strip should be as gradual as possible, as it is impossible to "iron out" these variations if they occur too rapidly and the mill operator is constantly altering his setting to cater for them.

Rolling

The foil stock is reduced to foil thickness in single stand mills which may be of the 2-high or 4-high type. Greater reductions per pass can be achieved with the 4-high mill, but opinions vary as to which is the better. The rolls are cambered in order to achieve uniformity of gauge across the width, due to the high rolling pressures involved.

Lubrication of the foil is necessary during rolling, mineral oil with additives being the usual lubricant.



Double rolling of foil.

The foil web is flooded with the oil prior to entering the rolls, and surplus oil is recirculated through oil filters which remove extraneous matter, including fine particles of aluminium picked up during rolling.

The gauge of the foil is controlled by the viscosity of the lubricant and the speed of rolling, so that under normal production conditions where the viscosity is constant, the gauge is maintained by rolling speed. Continuous contact mechanical micrometer gauges measure the thickness of the foil as it passes through the mill. The readings are shown on an instrument with a centre zero so that positive and negative variations are indicated by the pointer. For the thinner foils, down to 0·004 mm.—less than one-tenth of the thickness of the average human hair—non-contact gauges incorporating radioactive isotopes are used, in which the absorption by the foil of radiation from the isotope is measured. The U.K. and European standard of consistency is ± 8%.

Rolling of normal 0·009 mm. foil—which is the standard product for packaging—is accomplished by a series of passes through the mill, where up to 65% reduction is attained at each pass. Reduction to a finished gauge of 0·009 mm. can be achieved without intermediate annealing, although such an operation may be introduced. Generally, in the case of foil under 0·03 mm. thick, the final pass is made with a double web feed, i.e. two reels are fed into the mill simultaneously, with volatile spirit dripped between the two plies prior to rolling. This results in the foil having one surface bright and the other matt, the bright surface being that which is in contact with the rolls.

Separation and Annealing

When this two-ply rolling is adopted, the two layers have then to be separated. This is effected on a simple separating machine having a single unwind and a double rewind, the edges of the foil being trimmed in the process.

At this stage, the foil is in a hard state, and is softened by annealing at temperatures of 350° C. upwards. In addition to softening the foil, this procedure also removes residual oils from the rolling operation and sterilises the foil surface. Batch type forced air circulation furnaces, equipped with instruments for close control of temperature, are used for annealing, the times varying with the load, reel width and reel diameter.

Properties

The application of aluminium foil in packaging and other fields depends on a number of properties, which are considered briefly below. Their relative importance will depend on the particular application concerned.

The attractive appearance of aluminium foil is important from the point of view of sales appeal, particularly as it can be further enhanced by embossing, printing, colouring, lacquering and lamination with other materials. Combinations of transparent and opaque inks result in glittering wraps of considerable eye-appeal.

Foil wrappings are hygienic and non-toxic. They not only look clean and induce a feeling of cleanliness, they are clean; sterilisation by annealing destroys micro-organisms and the finished foil offers them no encouragement to thrive. The non-toxic qualities of aluminium foil make it possible to use it in direct contact with many types of food. No taste or odour is imparted by foil to the most sensitive foods, and it is being used in increasing quantity by the housewife for protecting food from absorbing undesirable tastes or odours in the kitchen, in the same way as manufacturers of food products use it to maintain the shelf-life of their products undefiled by adjacent goods.

Many acids have no effect on aluminium foil, but the many factors involved in chemical action make generalisations unwise. Cheese containing salt would react with foil, but this is prevented in practice by the use of a thin protective coating on the foil. Coated aluminium foil for wrapping cheese is covered by B.S. 1683 : 1950.

Because it provides a moisture barrier, foil prevents moisture loss or gain; it also gives protection against freezer burn of frozen moist products. Its lightproof qualities are useful in preventing rancidity in such products as butter and margarine.

Aluminium foil is radiant heat resisting—it reflects 95% of heat radiation falling on it—and therefore minimises gain or loss of heat by its contents. In conduction, foil cools quickly and heats rapidly, characteristics which are particularly useful in freezing and baking processes. It is also grease-proof and oil-proof and does not stain during oven use. In heavier gauges it is gas-proof, providing a complete barrier to oxygen and other gases.

From the point of view of the packaging operation, the dead fold characteristics of aluminium foil make it possible to fold or form it to varying shapes to provide a tight enclosure suitable for most purposes. The application of thermo-plastic lacquer coatings, plain or coloured, enable hermetic sealing to be effected simply by the application of heat and pressure. The flexibility and moulding characteristics are well suited to the operation of modern high speed wrapping machines.

Combined Materials

Strength, toughness and other desired characteristics required to meet the needs of modern high speed equipment are obtained by combining foil with plastic film or paper in lamination. Almost any sort of conditions can be met by a judicious selection of combinations.

When combining with paper it is usual to use an aqueous adhesive to bond the two components together,

then to drive off the water through the paper by passing the laminate through a drying tunnel and re-reel.

This procedure is not possible when combining with plastic film, since the water in the adhesive will pass through neither the foil nor the film. In this case it is usual to apply a thermoplastic coating to either the foil or the film, drive off the solvents with heat, and then bond the two materials together by passing through heated pressure rolls with the thermoplastic layer between. A more recent method of combining a plastic film with foil is by extruding the molten resin through a slit directly on to the foil. Polyethylene is being applied in this way.

Foil is also bonded to paper and film by means of waxes of the paraffin or microcrystalline types, with or without resin additions. The waxes are melted at elevated temperature and applied to either the foil or the paper. The two plies are brought together between nip rolls whilst the wax is still molten. The web is then chilled by passing over water cooled rolls which set the wax and give the bond.

Another form of bonding is that used for the inner liners of cigarette packets. Instead of the all-over application of adhesive, the latter is applied in a very thin line at intervals across the web, and the foil and paper are then bonded together at these points only—a method known as "glue streaming."

Aluminium foil, alone or laminated, is embossed by passing the foil between a design engraved steel roll and an impression roll of paper or similar mouldable material. Before running the material through, the engraved roll and impression roll are run together, to enable the latter to take up the pattern of the engraving. Sometimes two steel rolls are used, one with a positive pattern and the other a negative one, but this procedure calls for very accurate line-up of the rolls.

Printing of aluminium foil can be carried out by all the conventional techniques—flexographic, gravure, letterpress and lithographic. Inks specially formulated for printing on foil are necessary, and, furthermore, properties such as fat resistance, alkali resistance, etc., are required in some inks, depending on the product being wrapped.

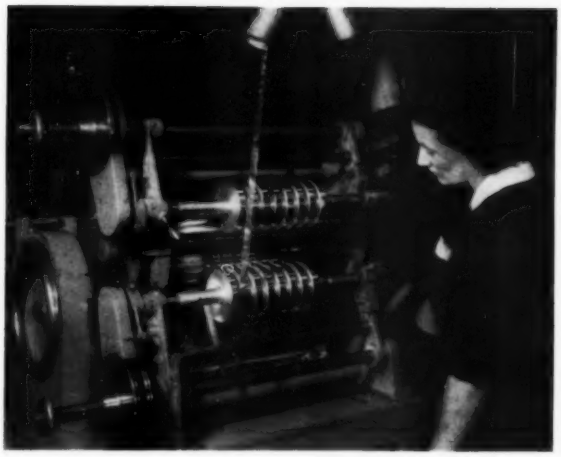
Applications

Packaging

The use of aluminium foil in packaging is so widespread that reference can be made here to only a few applications indicative of the range.

The annual consumption of aluminium foil in the United Kingdom for milk bottle caps is over 5,000 tons. Coloured and embossed caps from foil varying between 0·04 mm. and 0·065 mm. thick are applied on high speed bottle capping machines at rates of up to some 4,000 an hour, providing a perfect seal which can easily be opened without the presence of ledges where dust can accumulate. Besides milk bottles, a large variety of bottle caps and closures of varying colours and embossed patterns are in daily use.

The introduction of foil wrapping for edible fats in this country has developed on a large scale over the past few years. Foil laminated to vegetable parchment with a wax adhesive is used, and B.S. 2758 : 1956 has been issued to cover this material. This wrapper gives a long shelf-life, preventing loss of moisture from butter and margarine, in addition to retarding rancidity by excluding light.



Slitting foil into strip.

Major brands of high quality toilet soap are now sold in aluminium foil wrappers. Reaching the customer in the same condition as it left the factory, foil-wrapped soap has an extended life, which encourages large scale stocking with its attendant economies. Multi prints up to six units in register are used. This application, requiring properties not normally called for in printed laminated foils—alkali resistance and soap gel resistance—has been developed in collaboration with the principal soap manufacturers.

The sale of dehydrated soup powders in foil packs has been possible only due to the extremely good moisture barrier of the foil lamination. Another application requiring zero water vapour transmission is the packaging of pharmaceutical tablets. A 0·04 mm. foil laminated to cellulose acetate film on one side is used, two webs being heat sealed together with the tablet between. Photographic film wrapped in a foil lamination has been found to have increased shelf-life.

An interesting development in packaging is the tear strip used for opening food packages and cigarette packets. This is foil lined both sides with a plastic film and slit into very narrow strips: by pulling on this type the outer wrapper is torn away. This material has advanced a stage further in America where it is being used for weaving into textiles to give an attractive finish to certain fabrics. It can be made in various colours, simply by colouring the adhesive used for bonding the foil to the film. This application has not yet been fully developed in this country.

Containers

In the bakery industry, losses due to breakage may reach as much as 10% in transferring to paper cases, cakes, pastries and pies baked in tins. These losses have been almost eliminated by using cases made from foil 0·025 mm. and upwards for baking, shipment, retailing, reheating and serving, without any transferring. Similar cases can be used for frozen foods, the excellent heat conductivity of the aluminium allowing rapid freezing, and also permitting the heating of the foods for consumption without transferring to another container. These expendable containers eliminate, at comparatively low cost, the production expenses involved in cleaning,

drying and handling tins as part of the food preparation processes.

Electrical Industry

Very thin (0·005–0·006 mm.) foil is used in the electrical industry for capacitors, the foil being wound, interleaved with special paper which acts as an insulator. Foil for this purpose is referred to as slick foil, and is used for oil-impregnated capacitors. In recent years another type of capacitor, which is impregnated with chlorinated diphenyls instead of oil, has come into use, and in this case it has been necessary to ensure that the foil is completely wettable by water prior to use. For this type of capacitor, therefore, a completely oil-free foil is used.

The electrolytic capacitor uses a much thicker foil. Both commercially pure (99%) and the higher purity 99·8% or 99·99% aluminium is used, the commercially pure material for the cathode and the higher purity for the anode. These foils are etched by chemical or electrochemical means prior to anodising. The effect of etching is to increase the surface area of the foil, and gains of up to seven times the original area have been achieved.

Building

Thermal insulation has leapt into prominence recently in domestic, commercial and industrial life because of a new awareness of the importance of conserving, by using to maximum advantage, the natural sources of energy—coal, oil, nuclear fuels, etc. The Thermal Insulation (Industrial Buildings) Bill makes it necessary by law for new factory buildings to be efficiently insulated, and, progressively, for existing industrial buildings to be brought up to this standard. Apart from a lower consumption of fuel, the capital cost of air conditioning plant is reduced, because smaller heating units are required.

Aluminium foil is finding increasing application in this field. Alone, or combined with other materials, for roofs, walls, ceilings or floors, it reflects 95% of radiant heat—the largest factor in heat loss—and fulfils the dual purpose of keeping out excessive summer heat and keeping in the warmth in winter. Much more than half the heat transfer across air spaces of ordinary size faced with ordinary building materials takes place by radiation.

Laminated with kraft paper, foil provides an excellent house insulation if tacked down onto cross beams with an air space between the ceiling and the foil. It is also being laminated with new materials such as cellulose acetate wool for the same purpose.

Foil can also be bonded to slag wool slabs for use on furnaces as heat insulation, and to asbestos paper for making hot water pipe insulating sleeves, thereby reducing fuel consumption. It is also used for insulation purposes in curtain wall construction of buildings, where prefabricated wall units are fixed between the members of the structural steel skeleton. Sack units have infill panels and the foil bonded to the inner face provides a moisture barrier as well as insulation.

The relatively low cost of fixing, shipping, bundling and storing foil makes it economically attractive, and in addition to its resistance to the passage of moisture and thermal radiation, it is odourless, light in weight, vermin proof, and virtually indestructible.

An interesting example of the use of aluminium foil for thermal insulation—although not concerned with building—is provided by Mr. Donald Campbell's record breaking speedboat *Bluebird*. The extremely high temperature of the exhaust gases from the gas turbine engine could have caused serious distortion and weakening of the framework of the boat, but by the use of several layers of aluminium foil to insulate the exhaust, the transfer of heat was greatly reduced and the danger eliminated.

Other Uses

Burn resistant plastic topped tables have a layer of aluminium foil just below the top surface which rapidly conducts the heat away from a hot spot, such as the point where a cigarette end is touching the surface, and so prevents burning.

In the home, there is a growing use of foil in cooking, the natural juices being retained in the food by it being wrapped in foil during the operation. Wrapping of sandwiches, biscuits, etc., in foil keeps them fresh much longer by minimising moisture gain or loss.

Moisture losses by evaporation are prevented by laying foil round growing plants, and the exclusion of light prevents the growth of weeds. In the case of fruits such as strawberries, ripening is accelerated due to the radiant heat received by the fruit directly from the sun being augmented by that reflected upwards from the foil.

The heating of concrete floors by passing current through wires embedded in them has a parallel in houses and other buildings where concrete is inappropriate. In this case, the wires are laid on aluminium foil covered floors. The wires are spaced by 2 in. wide strips of light board grooved to protect them and covering the entire floor.

The uses of foil on the road include the prevention of premature cracking of road surfaces by laying it between the expanding joints in concrete layers and the bituminous asphalt top layer, as a reflecting medium in "cats' eyes," and in a line marking application.

During the last war, aluminium foil was used extensively as an anti-radar device. The foil, slit into narrow strips, was dropped from planes to give a false impression on enemy radar screens. Improvements in radar have necessitated an alteration of the material, but it is still basically aluminium foil.

In lithographic printing, foil of a minimum thickness of 0·07 mm., either plain or backed with paper, is being used for printing plates. One surface of the foil is grained and the required printing plate is produced by a photographic technique.

The potential uses of aluminium foil are limited only by the ingenuity of the user in taking advantage of its inherent characteristics to improve the quality and appearance of his products at an economic cost.

Recorder Generally Available

It is announced by George Kent, Ltd., that their Mark 2A electronic Multelec recorder, developed for and previously reserved for sale to the atomic-energy industries, is now made generally available to all industries. Its applications are as follows: for temperature measurement (thermocouple or resistance thermometer); for direct millivoltage recording; for industrial measurements depending on a radioactive source and ionization gauge, such as of level, material thickness, density, etc.; and for research work.

The Production and Uses of Aluminium Powder and Paste

By V. J. Hill, B.Sc.,

Research Laboratories, The British Aluminium Co., Ltd.

Following a brief description of the methods used in the production of finely divided aluminium, the author considers the properties and applications of both granular and flake forms, with particular reference to the influence of flake size and shape and of the choice of vehicle on the characteristics of aluminium paints.

FINELY divided aluminium is a commodity available in very different forms, ranging from the granular powder used in chemical, metallurgical and explosive applications to the smooth lamelliform pigment, either powder or paste, used in metallic paints and lithographic inks. It is in the latter form that aluminium powder is now most familiar; over the past two decades it has achieved a remarkable success in the fields of decorative and protective painting.

Granular Powder

Manufacture

Granular aluminium is normally produced by atomising molten metal as it issues from a small nozzle: a jet of air or steam impinges on the metal stream, breaking it up into small, more or less spherical particles, which solidify rapidly. The particle size of the product is controllable, to some extent, through the design and dimensions of the atomising head and the quantity and pressure of the atomising medium. The "blown" powder ultimately passes into large settling chambers, from which it is recovered and screened.

Properties and Uses

Aluminium powder in this form is rough in texture and dull grey in colour, lacking all metallic lustre. With such physical attributes it is completely unsuitable for paint formulation, although one of its principal uses is as an intermediate in the production of the more lustrous flake pigments. It is used also in metal spraying, powder metallurgy, and, with vinyl type resins, in "cold plastic solders," where its lack of metallic sheen is not detrimental. In its other applications, the chemical characteristics of the element, i.e. its great affinity for oxygen and or the exothermic nature of the combination are all important. Thus, granular powder is used for deoxidising steels to reduce porosity, and in the "thermit" process it is used to reduce metallic oxides in the preparation of carbon-free metals and their alloys. Ferric oxides may be reduced similarly, and the resulting metal used *in situ* for welding. More spectacularly, it is an active ingredient in pyrotechnics, incendiaries and high explosives.

Flake Pigments

Manufacture

The production of flake powders for use in paints descends from the ancient art of gold beating, in which foil was manually beaten out into fine particles. The less arduous processes developed subsequently are all based on the same fundamental principle, whatever the mechanical means employed, i.e. pressure is used to force the metal to flow into flake form before it work-hardens and disintegrates into the very fine pigment powder. Abrasion and grinding can, of course, reduce even massive metal to pigment proportions, but the product is invariably black and dull, and such actions are kept to a minimum in flake manufacture.

The oldest method of making flake powder involves the hammering of clean shredded foil scrap under heavy mechanical stamps, which are given a slight rotary motion as they fall, so as to burnish the powder during comminution. The screened powder from these stamping mills is finally polished to give a lustrous product. Alternatively, the foil scrap is ball milled with a lubricant, such as tallow or stearic acid, in the presence of an inert gas. Again, the product has to be polished.

The greatest advance in metallic pigment production was made by E. J. Hall in 1935, when he found that the comminution and polishing processes could be combined in a single ball milling operation to give a flake pigment in paste form. Either shredded foil scrap or atomised powder is charged into a ball mill, together with white spirit and with stearic acid, which at this stage serves as a lubricant to prevent welding together of the flakes. The sludge coats the polished steel balls which are carried up the side of the rapidly rotating mill, cascading downwards and subjecting the metal particles to countless impacts, hammering them into thin flakes. The sludge is then washed from the mill and fed to a filter press where excess white spirit is removed. The metal content of the filter cake is subsequently adjusted to specification by the addition of fresh white spirit and stearic acid, and the whole is mixed thoroughly to give a homogenous stable paste.

By varying the conditions of ball milling, e.g. charge and time, pastes with a wide range of particle sizes, from the relatively coarse "flitter" to the extremely fine inks, can be obtained. Pastes are also produced in which all or part of the white spirit is replaced by other diluents, such as naphtha, for use with certain synthetic paint components which have a limited tolerance for white spirit.

The advantages of this type of material are multifold: paste is easier to handle than powder, more compact and easier to disperse in liquids and, what is very important, free from the tendency to form dangerous dust clouds in subsequent processing.

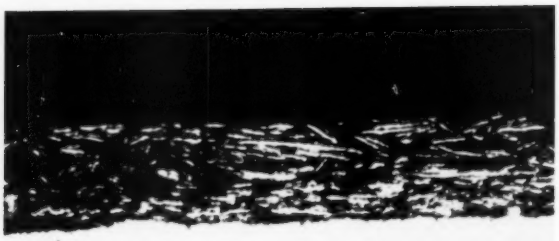


Fig. 1.—Section through an aluminium paint film. ×200.

Properties and Uses

The outstanding feature of aluminium flake is its versatility. It has found an application in powder form in the production of light weight or "aerated" concrete, and in the preparation of sintered aluminium powder compacts (S.A.P.), which are unique in retaining their mechanical strength at high temperature. As powder or paste it is used as the pigment in primers for wood and metal, in heat and light reflecting paints, and in purely decorative finishes. The more interesting properties of the pigment and their bearing on the various applications are worth examining.

Probably the most unusual property of aluminium flake pigment is the ability to "leaf." When the pigment is dispersed in a suitable oil medium and brushed out or sprayed, the individual flakes tend to rise to the air/liquid interface with their broad faces lying in the plane of, or parallel to, the surface, rather like fallen leaves. This effect is illustrated in Fig. 1, which shows a cross section through a typical aluminium paint film. Although the pigment is denser than the vehicle, particle size and shape, and the interfacial surface tension between the flakes and the medium are such as to hold the flakes in or near to the surface to form an almost continuous metallic film of high opacity. The hiding power of such a film is apparent from Fig. 2, which shows a cellophane panel painted on one side with a leafing aluminium paint containing a dark pigment: the flakes have tended to rise to the surface, completely obscuring the dark pigment which is visible from the underside.

Some pastes are deliberately treated in such a way as to destroy completely the leafing characteristic. The object is either (*a*) to produce a pigment which can impart a semi-metallic lustre to a paint film without obscuring any other coloured pigment which has been incorporated in the paint, and without losing the impression of depth of film, e.g. polychromatic metal finishes, or (*b*) to increase slightly the permeability of the paint film to improve adhesion in certain cases where the building up of a back pressure is possible, or (*c*) to minimise "grinning" through finishing coats.

The majority of applications, however, require the brightness and lustre which are provided only by the continuous metallic film of the well-leafed pigment. High light and heat reflectivities and low emissivity are properties associated with this type of finish, properties which have led to the use of aluminium paints in treating factory roofs to improve lighting efficiency, for painting petroleum and chemical installations to minimise losses by reflecting the heat of the sun's rays, and for coating radiating surfaces to reduce heat losses.

A clean polished aluminium sheet free from scratches has a total light reflectivity from its surface of 80–85%, most of the light is specularly reflected as by a mirror. A matte surface, on the other hand, diffuses the light uniformly in all directions. A well-leafed paint film has reflecting characteristics midway between these extremes, the average performance being 60–75% total reflectivity, of which the specular and diffuse components are roughly equal. Both the pigment and the vehicle influence the reflectivity of the paint film. As a general rule, the finer the pigment resulting from ball milling, the more specular the finish, although the total reflectance tends to decrease, probably because of the dark colloidal particles which are produced in the prolonged milling needed for the finer pigments. Pastes can, however, be burnished to increase their specularity without the formation of the undesirable detritus. The role played by the vehicle is more complex. The extent to which it promotes leafing determines the total reflectivity, but the degree of dispersion or flocculation of the pigment in the vehicle influences the specular/diffuse characteristics of the film.

There frequently seems to be confusion between the brilliance of aluminium paints and their colour. Fundamentally there is no difference between aluminium pigments as far as spectral colour is concerned. Brilliance on the other hand changes markedly as the proportion of specular to diffuse reflectivity varies; as the diffuse component increases relative to the specular the whiter the film appears, whilst a predominance of specularity gives the impression of blueness.

Closely allied to light reflectivity is the ability of the leafed film to reflect heat. The reflectance for a typical aluminium paint is about 70–80%, measured with an electrically heated nickel-chromium spiral as a heat

Fig. 2.—Hiding power of aluminium paint.

source. A more practical demonstration of heat reflectance is the record of the lowering of the ambient temperature by 9° F. on a sunny summer's day beneath an experimental galvanised roof painted with a good leafing paint, compared with an untreated roof.

Particle size and shape play important parts in the effectiveness of aluminium pigments for protection. Sieving tests, microscope counts or sedimentation analyses suffice to describe most particles, but another parameter, thickness, has to be considered with flake pigments. Flake thicknesses are generally less than 0·5μ, and they are estimated by evenly spreading a known weight of flakes, from which the lubricant has previously been extracted, on to water contained in a suitable trough. The flakes float on the water with their broad faces lying in the surface, and the area of the continuous unwrinkled film which they so form is measured. This value, known as the water-covering area, expressed in sq. cm. /g. is most frequently referred to, but the mean flake thickness may be calculated from the expression :—

$$\text{Mean thickness} = \frac{\text{Wt. of pigment in film}}{\text{Water covering area} \times \text{pigment density}}$$

In aluminium pigment production there is a tendency for the ratio of the mean diameter of the flakes to the mean thickness to decrease as the thickness decreases, i.e. small flakes are produced, with a consequent loss of "flakiness," as you attempt to produce thin ones. This is of particular interest in relation to the durability of aluminium paint films. It may be shown diagrammatically (Fig. 3), that the circuitous diffusion path through a paint film containing a lamellar pigment is longer than one through a film containing a granular pigment of the same cross section area also tightly packed. For the same mean area of flake, the thinner the flake the greater the number of flakes for a given weight of pigment and the greater the length of the diffusion path. But since the cross sectional area of aluminium flakes ultimately decreases as the thickness decreases, the diffusion path eventually becomes shorter. An optimum flake size would be expected for maximum durability of paint films pigmented at the same rate, and it has been shown in practice[1] that the durability does increase with water covering area, up to a limit of about 18,000–19,000 sq. cm. g. Beyond this, the advantage of the thinner flake is more than offset by the smaller cross section.

The protective properties of aluminium flake pigments are exploited in the field of steel priming, where the conventional paint has been red lead in linseed oil. As a basis for the protective painting of iron and steel, red lead paints have given very satisfactory results when applied over carefully prepared surfaces. Their slow drying and hardening time, poor can-stability, high cost, weight and toxicity, however, encouraged the British Iron and Steel Research Association to examine alternative paint systems. From exposure tests which they have recently concluded[2], it is apparent that some alkyd type paints pigmented with basic lead sulphate or zinc oxide, and a non-leafing aluminium flake pigment can provide excellent protection for ferrous metals, their performance being equal to, if not better than, the standard red lead primer exposed for comparison.

Parallel work[3] on primer paints for underwater service on steel has also shown conclusively the advantages of incorporating aluminium pigments in certain paints, the best formulation being a composite primer of aluminium, basic lead sulphate, barytes and iron oxide (Burntisland Red) in a phenolic-formaldehyde type of vehicle.

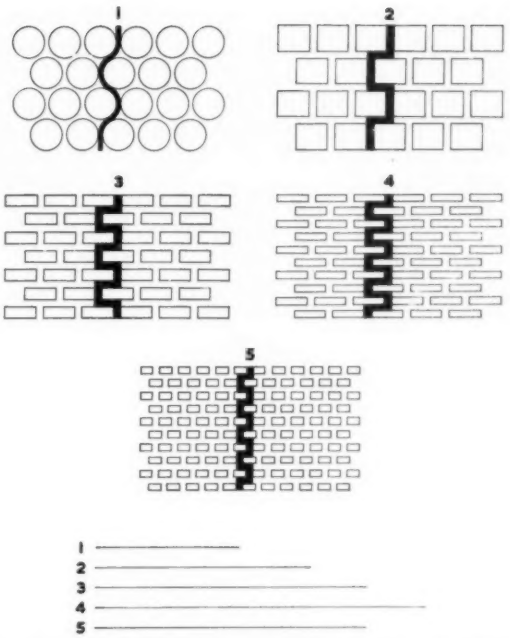


Fig. 3.—Diffusion paths through paint films pigmented with granular and flake pigments.

The success of these composite primers is difficult to explain. It is very probable, however, that the contribution made by the aluminium flake is the provision of high impedance to the diffusion of moisture or other corrosive media.

The sealing properties of a fully leafed film have been applied for many years in the priming of resinous woods to impede resin exudation, and also for the prevention of "bleed through" of oil soluble stains, tar, creosote and bitumen which could rapidly discolour light finishing coats in conventional systems. Little work seems to have been done in this country to evaluate leafing and flakiness of aluminium pigments in general wood priming. Recently, however, Lewis Berger (Great Britain), Ltd., and the British Aluminium Co., Ltd., carried out tests on newly erected glasshouses to compare lead-base with both leafing and non-leafing aluminium primers. After 3¼ years' service in a rural/marine atmosphere, there has been no conspicuous failure of any of the paint systems. A non-leafing blend of aluminium and other pigments in a linseed oil wood oil alkyd medium appears to be slightly superior to a fully leafing aluminium pigment in the same vehicle and to the lead-base standard. From their performance in these tests, it is apparent that some aluminium primers can be effective in preventing the destructive movement of timber resulting from alternate moisture adsorption and desorption, and that they are at least as good as conventional lead-based paints over which they have the advantages of lower cost, freedom from toxicity, and ease of application.

Aluminium Paint Vehicles

In formulating aluminium paints, the choice of vehicle

for the particular type of service envisaged is of the utmost importance. One of the common requirements of all vehicles, however, is that they should be inert as far as chemical reaction with the finely divided metal is concerned Thus, the acid value of moisture content should be kept low, since attack on the flakes leads to gas evolution which can create a considerable pressure in closed containers.

Where brilliance is a desirable feature of the paint, then the vehicle should be one which permits unhindered leafing. Lead driers are avoided in such formulation, since they completely destroy leafing in a very short time. Leaf retention in ready mixed paints has long been a problem, and some paints can still only be used to their best advantage by incorporating the aluminium pigment into the vehicle immediately prior to use. Among the modern synthetic resins, alkyds, which are much favoured for their durability, are prone to destroy leafing, but resins of this type are being developed to give reasonable shelf life for the paint. Cellulose lacquers are usually pigmented with leafing pigments, although they do not promote good leafing and give rise to " frosted " finishes.

Aluminium paints are now frequently formulated for specific application, e.g. the primer paints for ferrous metals. Another typical instance is the development of the modified silicone and butyl titanate paints for the protection of hot metal surfaces, even those exposed to weathering[4]. These paints withstand temperatures up to the melting point of the pigment (≈ 600° C.) without flaking, blistering or discolouring.

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2 Hudson and Stanners, *Journal of Applied Chemistry*, 1955, **5**, Part 4, April, 173.
3 B.I.S.R.A. Report of Joint Technical Panel N/P2.
4 Winter, *Journal of the Oil and Colour Chemists' Association*, 1955, **38**, Dec, 701.

Plate Mill Order

ORDERS for rolling mill equipment to the value of about £4 million have been placed with Davy and United Engineering Co., Ltd., of Sheffield, by South Durham Steel & Iron Co., Ltd., as part of their newly announced expansion programme to increase plate production. The plant includes two 150 in. wide 4-high rolling mills, each mill being driven by twin 4,500 h.p. motors, giving rolling speeds up to 1,020 ft. /min. These mills will be capable of producing high quality steel plate up to 136 in. finished width, as used by the shipbuilding and engineering industries, and output will reach 1,000 tons per eight-hour shift. The contract includes a wide range of ancillary equipment, including a 2,750 ton hydraulic hot slab shear, capable of cutting slabs up to 18 in. thick and 18 tons in weight.

Davy-United will also engineer and co-ordinate the supply and installation of some 8,000 tons of plate shearing and finishing machinery. To assist overall delivery of the whole plant this equipment will be manufactured by Vickers-Armstrongs (Engineers), Ltd., at their Elswick Works, Newcastle-on-Tyne, under Davy-United's engineering supervision. An arrangement now exists between these two companies whereby, in suitable cases, available capacity for steelworks plant can be increased in this way.

The plant will be built on a new site at West Hartlepool. Davy-United's responsibility embraces over 16,000 tons of machinery and the work will be spread over their Sheffield, Glasgow and Middlesbrough Works. Production of plate will begin in 1960, and by 1962 is expected to reach one million tons per year.

Birlec and Canadian Market

AFTER three months in Canada studying trade conditions, Mr. K. J. Palmer of Birlec, Ltd., supports the Canadian Trade Mission's statement that prospects are bright, and adds that, although the market is highly competitive, " We should get out there and get cracking." An office of the company has already been established in Toronto under the supervision of Mr. Palmer, whose present position with Birlec is that of London Office Manager. Depending on the outcome of Mr. Palmer's visit, there is a possibility that the Birmingham firm will not only sell in Canada, but may also manufacture furnaces there.

Until recently, Birlec, the Commonwealth's largest manufacturer of furnaces, has been prevented from tendering in Canada by the terms of licensing agreements with other companies. Now, however, with those agreements newly revised, Birlec is able to sell directly to Canada. Canada's furnace requirements, both for melting and heat treatment of metals, are growing rapidly, particularly as she is now ranked number four among the trading nations of the world, with every indication that even that position will soon be bettered.

British Driver-Harris in the South-West

BRITISH DRIVER-HARRIS CO., LTD., announce the opening of their South-Western Depot, at Almondsbury, about eight miles from Bristol on the main Bristol-Gloucester Road, and within easy reach of South Wales via the Aust Ferry. The address is British Driver-Harris Co., Ltd., Gloucester Road, Almondsbury, near Bristol (Tel. : Almondsbury 2342), and Mr. B. S. Lockett, assisted by Mr. Gwynne Thomas, is the manager.

The depot carries stocks of the full range of Drivex cables, and in the near future it will also hold supplies of electrical resistance materials, including the Nichrome series of alloys.

News in Brief

FOUNDRY SERVICES INTERNATIONAL, LTD., announce the appointment of Mr. B. Howard Williams as General Manager of their new associate manufacturing company, to be established during the current year within the environs of Sydney, Australia. Foseco are also hoping to commence manufacture in India in the very near future.

KENT CONTINENTAL SOCIETE ANONYME, the Belgian subsidiary of George Kent, Ltd., has moved into larger premises at 27 rue Paul-Emile Janson, Brussels.

THE Electricity Trust of South Australia has placed orders for transformers and switchgear with Australian Electrical Industries (Pty.), Ltd., acting on behalf of Metropolitan-Vickers Electrical Export Co., Ltd., to a total value of about £500,000.

THE London office and warehouse of John Allan & Co. (Glenpark), Ltd., manufacturers of non-ferrous alloys, is now at Thomas Road, Poplar, E.14 (Tel. : East 5411).

Aluminium and its Alloys in 1957

Some Aspects of Research and Technical Progress Reported

By E. Elliott, A.Met., F.I.M.

Senior Metallurgist, The Aluminium Development Association

Attention is drawn to work published in this country and the U.S.A., reporting research and technical progress in the various aspects of the metallurgy of aluminium and its alloys, including extraction, founding, fabrication, constitution, properties and standardisation. Reference is also made to interesting applications of these materials.

THE second half of the 1950's will probably be remembered as a period of contrast. As an example, the enormous growth in electronic means of communication has led to entertainment aimed at the lowest common denominator, provided by performers whose chief attributes are extreme youth and a complete absence of talent, but who have the all-important "gimmick" that the publicity experts can exploit. In this sense, the late '50's are the millenium of the mediocre and meretricious. On the other hand, the science and technology that enable this rubbish to be stored and transmitted with infinite fidelity are advancing at an ever increasing speed, and are representative of a period during which additions to knowledge have been made at a pace never before equalled. However much this rate may increase, 1957 will always represent the beginning of a new age—the age of space travel, whether manned or otherwise, because in the autumn of that year man first succeeded in putting an artificial satellite into orbit around this planet. So far as is known, that first satellite[1] is made of aluminium. The metal that facilitated the conquest of the air has had its part in the first step towards the conquest of space.

Production

Although the supply of and demand for aluminium have approached and receded from each other since the war ended, it was only in 1957 that there became available a surplus of ingot, as a result of the coming into operation of new extraction plants throughout the world. There is no doubt that demand will catch up again with supply, but in the meantime the challenge to develop applications is stronger than ever. West[2] has discussed the primary aluminium production facilities in countries throughout the world, and also future plans for extending and adding to them. He briefly summarises the new fields of development which should consume the metal made available.

Throughout its industrial history, aluminium has been produced by virtually the same method, that discovered by Hall and Héroult, and a tremendous amount of research has been directed towards improving and cheapening this process. Sandberg, Olsen and Eftestoel[3] have described investigations of crack formation in Soederberg self-baking anodes used in the electrolytic cell, and established a correlation between cracking and shrinkage during baking. They suggest that shrinkage may be minimised by selecting the correct granulometric composition of the coke aggregate in the anode paste; that is, the most suitable gradations in particle size. Although super-purity aluminium has been available commercially for a considerable period, its applications have expanded rapidly during the last few years. The three layer process for its manufacture has been described by Bloch and Muller,[4] with details of currents used, optimum composition of electrolyte, and methods of reducing electrode consumption. It is claimed that metal as pure as 99·999% aluminium may be produced, but no typical analyses are given.

Scrap and residues are very important sources of most metals, supplementing that extracted from the ore. One of the problems of the refiner is to know the composition of his raw material, and Platt,[5] in a review of non-ferrous metal scrap generally, has described how an experienced man can get some idea of type of aluminium alloy by such simple tests as bending and spotting with caustic soda. No doubt the expert is careful to note that with clad sheet beauty is only skin deep.

Melting and Casting

In Chambers' Twentieth Century dictionary, a symposium is variously defined as "a drinking together: a banquet with philosophical conversations: a collection of views on one topic: a merry feast." The symposium on metallurgical aspects of the control of quality in non-ferrous castings held by the Institute of Metals in 1957 was principally of the penultimate type, but when founders are gathered together both the first and the last definitions tend to creep in. Technically, Ruddle and Cibula[6] set the scene by a fully detailed consideration of the reasons for the occurrence of defects in castings and the scientific bases of methods of avoiding them. Confining himself to aluminium alloy castings, Carless[7] reviews the properties of the materials most commonly used and describes how they are controlled, mentioning precautions required with particular alloys, such as modification of LM6 and special fluxes for LM10. Carless also devotes attention to heat-treatment, and the care necessary with temperature control, quenching, and avoidance of distortion by sagging during heating. Defects must be discovered by inspection, or they may manifest themselves during service life, and Fry[8] describes the principal methods of doing this without cutting

up the casting, including visual examination, liquid penetration, pressure testing, ultrasonic testing, fluoroscopy, and radiography, with details of the defects revealed by this last technique.

Remembering Lord Randolph Churchill's dictum about lies and damned lies, one might approach the application of statistics to quality control with trepidation, but Martin[9] boldly—and most successfully—shows how it may be done with aluminium alloy castings.

Pressure die castings are different animals from those cast under gravity, and received separate consideration at the Symposium, Sharp[10] dealing with aluminium, magnesium and zinc alloys. He states his view that too much emphasis is placed on control of chemical composition, since pressure die castings are almost always abundantly strong for their purpose ; he notes, however, that corrosion resistance may sometimes be important, which surely brings one back to close control of composition.

The choice of aluminium alloys for pressure die casting has been discussed by Wolf,[11] who divides them into three types, namely those containing additions of silicon, silicon and copper, or magnesium, but gives little detail of the principal commercial alloys falling into these divisions. He is rather severe on the merit of aluminium alloy pressure die castings as compared with zinc-base, but overlooks their advantages for engineering applications where a reasonable proof stress value is essential. One of Wolf's criticisms is of the difficulty of obtaining on pressure die castings an acceptable decorative anodic finish. Hall[12] has considered the factors leading to this difficulty, principally under the headings of surface quality, composition, soundness, and anodising technique. He concludes that investigations at present in train, mainly on die design and thermal control leading to uniform metal flow, will result in the much wider availability of anodised pressure die castings, including those in alloys based on super-purity aluminium which will accept very bright finishes. Progress in this direction has been reported,[13] using special alloy compositions giving good colour anodised finishes, but the really high polish comparable with chromium plate is still elusive.

Pressure die castings are for mass production : the reproduction of the art of the sculptor requires a very different technique. Epstein's statue of Jesus of Nazareth for Llandaff Cathedral has been cast in aluminium-3% silicon alloy—a compromise between colour and castability—and Parrott[14] has provided a brief account of how the sculptor's clay is turned into metal, no detail of his work being lost in the process. Clay into aluminium ; this might be regarded as symbolic for the future, however distant.

The demand for improvement in mechanical properties has perhaps been less on casting than on wrought alloys, but nevertheless it comes from several directions. Thus to have an alloy offering high proof stress without heat treatment is most attractive, and therefore Gardner and Hinchcliffe's[15] account of experience in the foundry with the aluminium-zinc-magnesium alloy D.T.D.5008 is very useful. The foundry difficulties of the alloy are not disguised, but examples are illustrated of castings made by all three principal methods and typical applications are listed. Owen and Marsh[16] have described experiments on the American alloy 356 (LM16) with low iron content, giving test bars which, when fully heat-treated, have twice the elongation of the conventional alloy. They stress the importance of adequate degassing, and mention that quenching in water at 140° F. instead of at boiling point improves mechanical properties, although the possible effects of residual stress must be borne in mind.

Problems associated with the hexachlorethane degassing of aluminium alloy melts include possible iron pick-up from plungers, and the labour involved in correct handling of the tablets. A self-plunging degassing tablet[17] has now been introduced to avoid these troubles, weighted either by copper or manganese according to the type of alloy to be treated. That degassing may be effected by vibration of the solidifying metal has been shown by Southgate,[18] with aluminium-silicon alloy : he also lists other definite effects, namely reduction of grain size of pure aluminium, and reduction of intermetallic crystal size and decrease of gravity segregation in hypereutectic aluminium-iron alloys. This might be taken as establishing that rocking and rolling have some possible useful field of application after all.

The manufacture of ingots for working was revolutionised by the introduction of continuous and semi-continuous casting, and direct casting methods that feed the cast ingot straight into rolls are the logical extension. Easton[19] has reviewed these methods, including the Properzi, Tessmann, Goss, Hunter-Douglas, and Hazelett processes, and noted that the principal improvements in recent years have been towards dependable operation.

The huge new American forging and extrusion presses demand large ingots, and Taylor[20] and his colleagues have described modifications to semi-continuous casting equipment that have made possible the casting of billets in aluminium-zinc-magnesium-copper alloys as large as 32 in. diameter. By providing an interrupted quench it is possible to reduce the build-up of internal stress caused by thermal contraction. This is done by "wiping" away the quenching water from the lower regions of the billet by means of an air blast directed towards the metal surface.

Surface condition is very important on cast billets, and if machining can be avoided time and money are saved. Nielsen and Kondic[21] have studied the effect of a number of variables, including alloy composition, lubricants, mould scratches and casting speed and temperature on surface quality, as manifested by ripples, hot tears, scores, exudations and dross. They conclude that exudations are the most difficult defect to control, but with correct techniques they should be the only type that is not readily avoided. Using a specially designed equipment with a strong protective wall, Long[22] has studied explosions caused by dropping molten aluminium into water. He shows that explosions may be completely prevented by painting or greasing the inside of the water container, and also presents evidence that chemical reaction between the metal and the water does not enter into the explosion, which is due to the formation of steam.

Working

Most rolling ingots still have to be scalped, and an interesting description[23] has been published of a machine capable of removing the rough surfaces from slabs weighing up to 1½ tons. Ancillary equipment crushes

the swarf and removes cooling oil by centrifugal means, so that the scrap emerges ready for remelting. The Autumn Meeting of the Institute of Metals was held north of the border, and many a Sassenach had an opportunity to inspect the famous rolling mill at Falkirk. Richmond[24] has published an account of these works, from casting shop to packing warehouse, covering the manufacture of plate, sheet, strip, corrugated sheet, and material with special finishes, including continuously anodised strip up to 24 in. wide. The four-high rolling mills now so familiar for the cold rolling of aluminium strip date back only to 1936, and tandem mills only to 1940. The development of modern rolling mills has been traced[25] from the point of view of one of the best-known rolling mill makers, both in this country and abroad: examples are given of hot reversing mills and foil mills, in addition to wide strip mills.

It is well known that there are two methods of obtaining sheet and strip in intermediate tempers, namely temper rolling and letting down. Williams and Jones[26] have compared the two, pointing out the advantages to be gained by rolling all metal hard and obtaining other tempers by thermal treatment, but noting that for this to be attained furnaces must be developed with rapid heat transfer and accurate temperature control. In considering blisters on aluminium and its alloys, one cannot say of any single factor, with the confidence of Othello, that it is the cause; the possibilities are many. O'Dette[27] has shown that, with commercial purity aluminium sheet, micro-shrinkage near the surface of the original ingot has a predominating effect. In the absence of such shrinkage, ingots with quite high gas content had little tendency to blister. This tendency could be reduced by heating the ingot at high temperatures for extended periods, or by an initial cold reduction before hot rolling.

Internal stress in his material is the bane of the designer, particularly of highly stressed aircraft structures. After reviewing the possible effects of internal stress, such as distortion on machining, stress corrosion, fatigue fracture, and the like, Smith[28] points out that it is inevitably present in aluminium alloys subjected to a drastic quench as part of their heat treatment. In the case of material of constant cross-section, the effects of internal stress may be obviated by introducing an overriding stress by stretching the material to a predetermined strain, and Smith describes equipment for producing controlled stretched aluminium alloy plate for the manufacture of integral stringer sections and similar aircraft components. Turning from the thickest type of rolled product to the thinnest, accounts[29, 30] have appeared of new equipment installed by a well-known foil roller. This covers the process from foil stock through rolling to annealing, coating and laminating, and has added considerably to the country's capacity for a product which is still in increasing demand.

Following the introduction of roll-welded sheet, the availability of a product known as "tube in strip" has been announced.[31] This is made by casting rolling slabs incorporating rods of inert non-metallic material so that when the slabs are rolled to strip, they include continuous areas of powdered rod. These discontinuities may be inflated into tubular shape by pneumatic or hydraulic pressure. The product is made in aluminium up to 500 ft. in length, and has many applications, particularly in heat transfer.

One of the problems associated with the production of extrusions in aluminium alloys is that the temperature increases during the process, so that the tail end of a billet is appreciably hotter than the front. Mueller[32] has described a method of taper heating of billets to overcome this difficulty. It involves the use of a special three-section induction coil, the power input to each section being independently controlled. The advantage of extruding at reasonably constant temperature are listed. Extrusions in sintered aluminium powder have very high strengths, usually put down to the effects of the oxide in the compact. Cole[33] has investigated these effects, extruding packs of both aluminium discs and of foil "confetti"; he shows that when an aluminium powder grain is extended during extrusion, the natural oxide film breaks up into discrete platelets, leaving sufficient detritus along the extended boundary to impede crystal growth and slip.

Heat-treatment and annealing are essential operations in the metallurgical art, and the higher strength aluminium alloys depend for their mechanical properties on controlled thermal operations. These have been reviewed by Williams,[34] who considers the main types of furnace at present in use, the effect of rate of heating and cooling and problems such as staining and distortion. He emphasises the need for improvement in rate of heat input. In another article,[35] the same author concentrates on one particular problem, namely the effects of overheating during homogenisation or solution treatment. He shows that the effects on the final product of overheating at these two separate stages are different; in both cases rosettes of liquated material may be seen, but films are formed at the grain boundaries of the cast structure by overheating the billet, while they are present at the recrystallised grain boundary in material overheated during solution treatment. Forgings present special heat-treatment problems, particularly as, due to their complex shape, they cannot usually be stretched to remove the effects of residual stress. Wilson and Scanlan[36] have given a general account of the heat-treatment of forgings, and of quenching in boiling water, together with some thoughts on other possible quenching media. Heat treatment and billet heating require furnaces, and METALLURGIA[37] has presented its annual review of new installations, as usual well illustrated. This is a most valuable and full account of the most modern furnaces being used throughout the metal industries. Examples in the aluminium industry include a preheating furnace for rolling slabs, a continuous flash annealing furnace for sheet, and furnaces for solution treatment and precipitation treatment.

In addition to being stress-free, it is important that plate for machining into aircraft components should be sound, and non-destructive testing for internal defects is conveniently done by ultrasonic means. Equipment is now available to permit automatic scanning, by immersion of the sample and probe in a tank of water. A description[38] of this method also illustrates a typical chart record.

The increasing demands for exactitude of form in aircraft skins have led to great interest in chemical milling and contour etching. Sheppard[39] has listed the chief advantages of these processes over conventional machining, including economies in machine tools and saving in weight, and described and illustrated a number of examples of chem-milled components. Forrester's[40]

article on chemical milling and contour machining is a review of the present position, and he quotes from authorities on both processes. An interesting table shows the amount of overweight resulting in a typical fighter aircraft if thickness tolerances on the skinning are allowed to increase on the positive side. Another problem in aircraft construction is the cutting and trimming of honeycomb structures, because of the fragile nature of the cell material. An American company[41] has overcome this difficulty by filling the material with water which is then refrigerated, the resulting frozen mass may be cut, slotted and milled rapidly without distortion.

Much water has flown under the bridge since M. Francois Appert first preserved food in hermetically sealed containers, and the demand today for light, easily handled, throw-away cans is tremendous. This is a field from which aluminium is barred in this country only by price considerations, the technical problems having been solved. In some countries, the economic barrier is easier to surmount, and a German company[42] has installed a completely automatic line for aluminium can-making. The cans are impact extruded and the line includes degreasing, lacquering, baking and printing equipment.

Interesting accounts have appeared of two famous works using aluminium and its alloys. The Fordhouses works of Marston Excelsior, Ltd.,[43] produce a wide range of articles by rolling to shape, pressing, welding, brazing, machining and other operations, and a great variety of products is illustrated in a comprehensive account of the company's activities. Heat exchangers of many types are manufactured, including radiators for an impressive list of high quality cars, and other fabrications range from a floating water purification plant to a sluice gate, and a paint storage vessel to aircraft fuel tanks. Warwick Production Co., Ltd., are principally concerned with the manufacture in aluminium of returnable containers of various sizes, and descriptions[44, 45] have appeared of their recently enlarged premises, including pressing, spinning, welding and assembly shops, and finishing departments. An account is given of the processes involved in the production of a typical deep-drawn aluminium container.

Joining

Although correct design, equipment and technique are so important in welding, the application of fundamental metallurgical principles is more vital still. In introducing their paper on the metallurgy of welding aluminium, Pumphrey and West[46] note that the making of a weld is the whole of metallurgy in miniature, and it is on this basis that they develop their argument, listing the common defects in welds, and the factors causing them. Post-weld treatments to improve weld properties receive special consideration.

The most popular methods of fusion welding for aluminium and its alloys are those based on the inert-gas shielded arc. Creswell[47] has studied the effect of impurities in the shielding gas argon; he shows that nitrogen, hydrogen and water vapour are the principal offenders. The effects of the last two on aluminium are well known; in the case of nitrogen, contents above 0·05% cause interference with welding of aluminium-magnesium alloys by the formation of magnesium nitride. In a review of shielding gases for welding, Helmbrecht and Oyler[48] generally prefer argon for aluminium, but point out that helium may be used for direct current welding, and half and half mixtures for thick plate where advantage may be taken of both the high heat input associated with helium and the cleaning action of argon. These authors state that the addition of a small proportion of oxygen to argon can, in certain types of welding, improve weld soundness.

Turning to the electrical side of the gas-shielded welding process, an interesting summary has been provided by Welch[49] of recent direct current rectifier-type power sources designed for consumable electrode welding. He explains the virtues and deficiencies of the various types, and notes that regulated rectifier welders compensate for all primary line variations except very large rapid fluctuations. Young[50] has described a constant potential power source for self-adjusting arc welding, which, in his opinion, represents the biggest forward step in aluminium alloy welding since the consumable electrode method was first introduced, because the use of a constant pre-set wire speed simplifies selection of welding current, starting is easy and equipment is light and relatively inexpensive. In considering electrical equipment for automatic welding, Tuthill and Mann[51] concentrate on low voltage with high current densities, and in their view under these conditions arc voltage has little effect on burn-off rate, the current being held constant by feeding the wire at a fixed speed. They illustrate equipment for the automatic welding of $\frac{3}{32}$ in. aluminium sheet by the argon-shielded consumable electrode process, used to join coils for rolling. Mann and Purkhiser[52] have applied automation to inert-gas tungsten-arc welding of aluminium alloys, and designed an alternating current source that provides a stable arc, rectification of the straight polarity half of the voltage wave being used to provide direct current for the motor controlling the arc length. Examples are given of work done with this equipment, which is considered particularly suitable for industries requiring very closely controlled welded assemblies, as, for instance, in aircraft manufacture.

In a description of experience in welding aluminium alloys by the inert gas metal-arc process, Wilson[53] points out that all aluminium alloys can be welded, but that not all are in the "weldable range." He defines this range as covering those materials which will not only produce an inseparable joint under heat, but will also provide the required joint properties. This is, of course, a very flexible definition, but on the other hand it is also practical and probably as good an approximation as can be made at present. Wilson's paper is a detailed and very useful account of investigations into the effect of weld variables, and also of work in the field both with the self-adjusting arc and argon-arc equipment. Having in mind Wilson's definition, it would generally be thought that clad aluminium-zinc-magnesium-copper alloys of the D.T.D. 687A type fall outside the weldable range, but Tyler, Terry and Moore[54] have brought them within it by a rather complicated post-weld treatment, involving hot working and prolonged soaking at the solution treatment temperature during re-heat-treatment. Actually, these workers used an unclad sheet material, but there seems no reason why clad sheet should not be similarly treated, particularly as with this alloy diffusion into the cladding is less of a problem than with aluminium-copper-magnesium alloys. The advantages of

working welds have also been shown by Meredith and Russell,[55] who applied cold work by planishing, followed, where suitable, by re-heat-treatment.

Tait[56] has tackled the difficult task of providing costs in pence per foot for the consumable electrode welding of aluminium alloys, as part of a survey of welding costs for various metals. He compares the total costs arrived at with those for argon-arc welding and for manual arc welding of mild steel; inert-gas metal-arc is always cheaper than argon-arc, and usually appreciably cheaper than mild steel welding. Although some application has been made in industry of the welding of wrought to cast aluminium alloys, little has hitherto been published about the properties of such joints; Bailey, Hirschfield and Horwood,[57] however, have now provided a preliminary survey of certain wrought/cast combinations. In no case were very high weld strengths or weld efficiencies obtained, and elongations tended to be low and very variable. The authors point out that different welding procedures and material sizes may produce quite different results.

Although ringing out the old and in the new is an enjoyable activity, it is nevertheless important to avoid throwing out the baby with the bathwater. Accordingly, Koziarski[58] has looked at the oxy-hydrogen, oxy-acetylene and inert gas shielded methods of welding aluminium alloys, and concluded that the flame methods have advantages for thin material. For very thin sheet, oxy-hydrogen may be the easiest method, but in general oxy-acetylene is to be preferred.

Resistance welding is widely used in the aircraft industry, and Dickinson[59] describes how its application has been extended by the introduction of equipment for the spot welding of large double-contoured panels. These machines have throat-depths as great as 70 in., with 100,000 amp. of current available, and are used in the construction of the new American jet airliners. Spot-welding is also valuable in land transport, as has been shown by Burton[60] in his general account of the continental railway applications of this method of joining. He mentions particularly the manufacture in France of aluminium alloy roofs for goods wagons, and the famous German rail-cars which are made principally from aluminium-magnesium-silicon alloy. Davis and McMaster[61] have studied the effect of variations in tip force and radius on electrode life when spot-welding aluminium-2½% magnesium alloys, and they conclude that the optimum values are 1,050 lb. and 10 in. respectively. What has been so aptly called the idiot's lantern enters many phases of modern life, and the technical applications of television are increasing rapidly. Dickinson[62] describes the use of closed-circuit television to view the side of a spot-welded joint remote from the machine operator, and so detect electrode pick-up by the appearance of both sides of the welds. Previously, this involved the employment of a second observer, who now no longer needs to serve by only standing and waiting, but may post o'er land and ocean without rest, or even perhaps do a little welding himself.

Pressure welding of aluminium has not progressed so rapidly as might have been expected, but Tylecote[63] is able to point to several examples of its application in his review of the subject. They include the manufacture of tube for cable sheaths, the roll-welding of refrigerator evaporator plates, and the joining of billets in the direct extrusion of cable sheathing; the cladding of alloys with pure aluminium or other alloys is, of course, well known. It is with this aspect of pressure bonding that Storchheim[64] is concerned, and he shows that bonding pressure is a critical factor and affects the microstructure of the intermetallic diffusion zone. He suggests that a third ordinate of pressure might be added to the constitutional diagrams of binary systems.

Many accounts have been published of practical applications of the welding of aluminium. Bradway and Serroi[65] have described the welding of superstructures for destroyers for the American Navy in which prefabrication played a large part. In this country, Muckle[66] has considered the design problems posed by aluminium deckhouses on steel ships, and has made intriguing suggestions about the advantages of very light connections between the house and the deck. The deck edge elevator[67] on the attack carrier U.S.S. *Ranger* is the largest all-welded aluminium structure yet made in the U.S.A.; it includes more than two million pounds of aluminium alloy. The aircraft using the elevator will themselves contain welded components; Copleston[68] has reviewed the applications of argon-arc welding in aircraft construction, covering many metals including aluminium and its alloys. Aircraft carry bombs, and Kunkler[69] has shown how both tungsten-arc and consumable-electrode welding have accelerated the production of very large aluminium incendiary bombs. Petrol is well known to be a very "searching" liquid, so that the fabrication of aluminium tanks[70] for petrol tanker lorries is an excellent test of weld quality; this is being done by an American company, using automatic and semi-automatic consumable electrode welding. Sullivan and Gower[71] have described how a change from argon-arc to automatic consumable-electrode welding for the attachment of a cast ring carrier to a forged piston has quadrupled the welding speed.

A completely new industry is making very specialised demands upon many others, namely that devoted to the production of nuclear energy. Terry, Shuttleworth and Moore[72] have given several examples of welded aluminium parts for this purpose, including vessels, pump housings, heat exchangers, and items of chemical plant. This paper includes a most impressive macrograph of a section of a butt weld in 5 in. thick aluminium alloy. Reference is made to many thousands of feet of aluminium pipework, joined by argon-arc welding, in a general account of the welding of units for nuclear power stations.[73] Lancaster[74] describes the welding of tanks in pure aluminium for experimental reactors; he considers high quality welds more difficult to attain in aluminium than in steel, and calls for further research and development work.

Large demands for aluminium tubing at prices lower than those attainable by conventional production methods have led to the development of processes involving the forming and welding of strip. Rudd[75] has described how this is done by high frequency resistance welding, at speeds as high as 250 ft./min. Another approach has recently been made in this country[76] using a train of forming rolls leading to an argon-arc welding head, which welds the open joint tube fed under it. One of the principal applications of such tubes is in overhead irrigation equipment. Jettisonable fuel tanks for aircraft may be regarded as large closed tubes, and an American company[77] is applying mechanised tungsten-arc welding to their fabrication with such success that

one 200 gal. tank is produced every four minutes. To recall a wartime phrase, these babies will have to be dropped at a great rate to outstrip the production capacity.

Considerable interest was aroused by the presentation in this country by Rykalin[78] of a paper on welding in the Soviet Union, and it has now appeared in print with additional material arising from the discussion. Reference is made to the semi-immersed arc welding of heavy aluminium plate, the layer of flux being sufficiently thin to allow gases to escape through it. What the welder hath joined, let no man put asunder; however, welding equipment may be modified and used for cutting. Hucklesby[79] has described the development of tungsten-arc cutting of aluminium, using nitrogen as the shielding gas. His paper includes some excellent photographs showing the smooth cut edges obtained, and evidence that the heat-affected zone is extremely shallow.

Aluminium is brazed by three principal methods, namely torch, furnace and flux-dip. In a review of the last technique, Rosseau[80] lists the wrought and cast aluminium alloys suitable for this type of brazing, and states the correct sequence of treatments involved. He mentions as an innovation the use of powdered solder-flux mixture, which is brushed on as a slurry and remains adherent after preheating, releasing the brazing alloy when its melting temperature is reached. This paper is one of several on brazing in the same journal issue, and some notes[81] introducing them give information on fits, clearances and assembly. There seem to be two uninformed opinions about the soldering of aluminium; one, that you can't do it, and two, that it is the most suitable subject for the taking out of patents. Zinc forms an excellent solder for aluminium, albeit of rather high melting point, and Robinson[82] has described the correct techniques and fluxes, and given examples of applications. He emphasises that zinc-soldered joints are the most corrosion-resistant soldered joints that may be made with aluminium.

The idea of sticking metals together is now quite familiar, and Williams[83] has reviewed the present state of the art, covering joint design and efficiency, the effects of elevated temperatures, and the new methods of sandwich construction in the aircraft and other fields. Dunn[84] has made a similar survey of the application of Araldite to light metals, including examples of joints in assemblies varying from a fire hydrant stand-pipe to railway luggage racks. He also refers to the use of surface coating resins, which have many applications, including the protection of collapsible tubes and food cans, and to resin press-tools for the forming of sheet. In Germany, adhesive-bonded joints are not used for highly stressed components at present, but Matting and Rubo[85] have shown that the process is gaining ground.

Last, but by no means least, Williams[86] has provided a useful account of the problems facing the rivet manufacturer, including dimensional tolerances, peripheral coarse grain and grain growth on heat treatment. Some reference is also made to the confusion caused by the existence of three similar types of aluminium-magnesium-silicon alloys, namely HE10, HE20 and HE30. Let us, with Shylock, welcome a Daniel to judgment.

Constitution

Clark and Rhines[87] have used a diffusion couple to determine the number of intermetallic phases present in the aluminium-magnesium diagram between 30 and 60% magnesium. This technique depends upon the principle that if such a couple is annealed at a given temperature for a long time, all the phases of the binary system which exist under equilibrium conditions at the diffusion temperature will form intermetallic layers. According to Clark and Rhines, at 335° C. three intermetallic phases exist, namely the β (Al_3Mg_2), γ ($Mg_{17}Al_{12}$) and ϵ. Applying a similar method, Castleman and Seigle[88] are studying the aluminium-nickel system, and note that four intermetallic phases occur, β ($NiAl_3$), γ (Ni_2Al_3), δ (NiAl) and ϵ (Ni_3Al).

Raynor and Ward[89] have investigated the constitution of the aluminium-rich alloys of the quaternary aluminium-iron-copper-nickel system in the solid state at 530° C. by metallographic, X-ray-diffraction and electrode-potential measurements. The compositions of two intermetallic phases have been established as $FeCu_2Al_7$ and $NiCu_3Al_6$, and the results are discussed in relation to recent suggestions as to the general nature of aluminium-rich intermetallic compounds formed by aluminium and the transition metals.

Contents of manganese and/or chromium in the high strength aluminium-zinc-magnesium-copper alloys are necessary to obtain the required mechanical properties, but they must be added with circumspection, since excessive amounts can cause segregation of brittle constituents. In investigating this phenomenon, Day[90] has determined the boundary of the primary aluminium phase field for an alloy of basic composition Zn 5·75%; Mg 2·5%; Cu 1·25%; Fe 0·2%; and Si 0·2%; and has shown that the limits of this field conform to the rough approximation that the sum of the manganese content plus three times the chromium content must not exceed 1%. This threefold potency of chromium as compared with manganese is remarkably constant in aluminium alloys, whether the effect concerned be beneficial or otherwise.

Properties

Single crystals continue to attract the research worker, and Auld[91] and his co-workers have used X-ray microscopy to study slip formation in crystals of super-purity aluminium grown in the form of flat tensile specimens. They illustrate in strained crystals two systems of transverse parallel lines, corresponding to primary slip planes and kink bands. Wiseman, Sherby and Dorn[92] compare single crystals and polycrystals in creep, using aluminium, tin and lead, and show that both types of specimen have the same high temperature activation energies for creep, and these energies also agree with those for grain boundary shearing. Working with bicrystals in pure aluminium, Tung and Maddin[93] have found that the activation energy for grain boundary shear increases continuously as the boundary angle increases, in specimens having a pure tilt boundary about the 110 axis. The conclusion is drawn that the mechanism for grain boundary shearing is a combination process involving slip and grain boundary diffusion.

Carreker and Hibbard[94] have performed constant strain-rate tensile tests on high purity aluminium over a wide range of temperatures, namely from 20° to 873° K. Various grain sizes were obtained by annealing at different temperatures, but no systematic effects of the variations were established. Evidence was noted of the operation of strain ageing during the tests. Solid

solution alloying, using copper, magnesium and zinc, has been investigated as a means of improving creep resistance by Gemmell and Grant,[95] and while the first two addition elements were highly effective, zinc gave little or no benefit. Tests were made at 500°, 700° and 900° F., and at the lowest temperature with high alloy contents intercrystalline cracking occurred at high strain rates, while at lower strain rates and also at higher temperatures cracking was transcrystalline, as a result of grain boundary sliding and migration. Intercrystalline cracking in creep has been noted by Nield and Quarrell[96] in high purity aluminium-1¼% manganese and aluminium-5% magnesium alloys. They conclude that this form of cracking is controlled by the relative extents of grain boundary sliding and migration; with the aluminium-magnesium alloy intercrystalline fracture was observed in a central range of strain rate, while outside this range fractures were ductile.

Turning to alloys with definite ageing characteristics, Thomas and Nutting[97] have used the electron microscope to study the plastic deformation of aluminium-4% copper and aluminium-7% magnesium alloys. Slip lines are shown to pass through particles of coherent precipitates, but to bend round non-coherent phases. Of considerable interest is the finding that when precipitation takes place preferentially on grain boundaries, plastic deformation may be confined to the adjacent denuded regions. Underwood[98] has tested aluminium-copper alloys in creep over a temperature range of 200° to 540° C., using quenched specimens so that ageing could start simultaneously with the application of the creep load. The precipitate induced under stress was in finely dispersed platelets, while that in unstressed specimens consisted of widely spaced spherical particles. The time to maximum hardness was found to decrease as stress increased.

The introduction of casting alloy LM21 to B.S. 1490 was preceded by investigations of its mechanical properties and corrosion resistance which showed that it was not inferior to alloy LM4 in these respects; the two alloys are both of aluminium-silicon-copper type, but, LM21 has a higher permissible content of zinc. The relative creep resistance of the alloys has now been determined at 200° C. by McKeown and Lushey,[99] who conclude that there is no marked difference in behaviour during a period similar to the normal life of an internal combustion engine.

Chapters of a forthcoming general book on the fatigue of metals have been appearing as journal articles, and two of these are of special interest. Forrest[100] has contributed the article on the fatigue properties of aluminium alloys. He considers the various alloys in groups, and compares their general fatigue behaviour, the effects of notches and of residual stress in the materials, the role of surface finish, and the results of tests made in corrosive environments. The fact is brought out that the fatigue ratios of the high strength alloys are low as compared with those of lower strength, a most important point in designing structures subject to fatigue loading. The chapter on welds is written by Whitman,[101] who deplores the paucity of data on the fatigue properties of welded joints in many metals, including aluminium alloys. Such information as is available indicates low fatigue values, and more work is required.

Forsyth and Stubbington[102] have continued their investigations of fatigue mechanism, using aluminium-copper, aluminium-zinc, aluminium-silicon, aluminium-copper-tin, and aluminium-copper-magnesium alloys, and found the process to be one of overageing or depletion of solute atoms, leaving soft spots which deform plastically. A particularly interesting finding is that a crack, once started, might produce depleted zones immediately ahead of its root, and so progress independently of existing soft spots. In a metallographic study of the tensile and fatigue properties of an aluminium-zinc-magnesium-copper alloy to D.T.D. 683, Broom *et al.*[103] have found catastrophic softening on certain planes in the late stages of both types of test. These planes are identified as the sites of extensive slip, and a number of possible causes of their development are discussed, several of which would fall under the general classification of over-ageing. Reviewing the fatigue properties of heavy metals, Cuthbertson[104] refers to the new aluminium-tin bearing alloys containing high contents of tin, and gives results of tests on aluminium-30% tin alloys, with and without copper additions. He mentions that engine tests on the binary alloys have led to most encouraging results. The availability in this country has been announced of Alzen 305,[105] an alloy of about 40% aluminium, 10% copper and the balance zinc. This is a bearing alloy and its properties are summarised, but no fatigue or creep data are included

Grow old along with me, the best is yet to be—according to Browning, and certain aluminium alloys abide by this dictum. Polmear[106] has made a systematic study of the ageing characteristics at various temperatures of wrought aluminium-zinc-magnesium alloys containing 4 to 8% zinc and up to 3% magnesium. The important effect is demonstrated of small quantities of the latter element on the development of high strengths, and evidence is adduced for the existence of two stages in the ageing process; identification of the phases, however, was not attained. Similar work has been done by Chitty[107] on aluminium-copper alloys with additions of silicon, manganese and iron. These elements did not alter the general form of the aluminium-copper ageing curves, but silicon in solid solution at the solution treatment temperature increased the rate of ageing and the quenched hardness value, while manganese similarly in solution raised the quenched and peak hardness values, and the increment between them. Excess of iron producing an $FeAl_3$ phase increased the quenched hardness to some extent.

The phenomenon of reversion has been studied in aluminium-copper, aluminium-copper-magnesium and aluminium-silver alloys by Beton and Rollason.[108, 109] They show that hardness reversion in naturally aged alloys is due to solution of the decomposition product associated with the formation of a flat in two-stage primary age hardening curves. Aluminium-copper alloys are easily revertible, while difficulty is experienced in reverting aluminium-copper-magnesium alloys, due to the wide ranges of temperature and composition over which two-stage ageing takes place. With aluminium-silver alloys, reversion must remove the hardening effects of at least two decomposition products.

Entwistle[110] has shown that during the ageing of super-saturated single-phase solid solutions in aluminium-copper-magnesium-silicon alloys a transient maximum of damping capacity is exhibited. He suggests that the progressive increase in damping with degree of super-

saturation can be used to determine the solid-solubility limits at solution-treatment temperature. Hardie and Parkins[111] dissolved copper, germanium, magnesium, silver, zinc and silicon in aluminium to give binary alloys suitable for the study of solid-solution hardening. They establish a linear relation between concentration and hardening effect, and between hardening and the distortion produced in the lattice by the solute. The variation of Young's modulus with composition is reported for a series of binary aluminium-rich solid solutions by Elliott and Axon.[112] Unfortunately, they give their results in the C.G.S. system, and eyes accustomed to figures in millions of pounds per square inch find kilogrammes per square millimetre singularly uninformative. These authors find a low value for the modulus of very pure aluminium, and show how all the addition elements tested increase this value, silicon being the most efficient in this respect.

Aerodynamic heating looms large in the designer's mind when high-speed aircraft and missiles are under consideration, and general opinion seems to be that aluminium alloys are unsuitable for really fast machines. Steurer[113] has shown, however, that for very short periods of exposure to temperature, metals have properties far superior to those obtained in conventional tests, and they may therefore resist the transient heat conditions of flight. He also considers that metals may have a part to play as heat absorbers, or in protection of other structural materials. Aluminium powder products are noted for their resistance to high temperatures, and Lenel, Backensto and Rose[114] have measured the mechanical properties of powder extrusions at room temperature and 400° C. They find that the tensile and yield strengths of these materials relate to the particle size and flake thickness of the powder; strangely enough, the proportion of oxide has only a very minor effect, except in so far as it depends upon flake thickness. Lenel has also reported on the metallography of aluminium powder extrusions, this time with Ansell and Nelson.[115] By electron microscopy it was established that the oxide particles appear as platelets approximately 100Å thick in experimental extrusions, while in commercial products the platelets seem to be partially or completely spheroidised.

Whiting[116] has presented an interesting report on the testing of 50 to 70 ton hopper wagons made in aluminium alloys. These vehicles were constructed by welding from alloys equivalent to HE20-WP and NP5/6-M. Static and impact tests were applied, and also shake-out fatigue tests, and they confirmed that the design of the wagons was quite adequate for their purpose. A large British foil company recently opened a new wing to its laboratory and the facilities and testing programmes have been described,[117] covering work on the foil itself, laminating materials, and lacquers and inks. An intriguing account[118] of an aluminium alloy put on the market in 1912 in Australia includes a comprehensive report by the National Physical Laboratory, giving test results in tension and compression, hardness values and impact tests. There is also a letter from the chief engineer of a steamship, expressing the opinion that the alloy " will be of great advantage in marine furnishings, etc. " Plus ça change, plus ç'est la même chose.

Corrosion and Protection

The uses of aluminium and its alloys in chemical engineering are well-known, but additional information is constantly being accumulated from laboratory tests and service experience with various chemicals. McKee and Binger[119] have assembled evidence, covering over 30 years, of the suitability of aluminium for contact with low molecular weight fatty acids and anhydrides at temperatures up to about 50° C., and to certain acids and concentrations up to boiling temperature. In a review of experience with the storage and handling of glacial acetic acid, Manning[120] recommends aluminium for tanks, but points out that corrosion may be experienced with dilute acid. He records experiments to establish that certain failures due to pitting were caused by high chloride in the diluting water, but, surprisingly, addition of mercury salts failed to duplicate the attack experienced in service.

Bruns[121] has compared the behaviour of alloy steels and aluminium-coated steels in hot hydrogen sulphide, and found that while all the aluminium-coated specimens had marked resistance to attack, calorised coatings were the best. In order to assess the suitability of materials for a hydrogen sulphide-water absorption plant, Bradley and Dunne[122] constructed pilot equipment and carried out corrosion evaluation tests. They recommend materials for various parts of the plant, and state that aluminium conduit, instrument tubing, building sheet and fencing would provide long-term service in this environment. Marshall and Hugill[123] have made tests in New Zealand on the effect of natural steam from boreholes on various metals. This steam is contaminated with chlorides, hydrogen sulphide and carbon dioxide; an aluminium-1¼% manganese alloy (NS3) was one of the metals tested, and suffered little corrosion loss, although some pitting was noted. Much has recently been heard of the effect of high purity water at high temperatures on metals, and Roebuck and his collaborators[124] have added to the information available. Among the materials they tested was aluminium, which showed high resistance up to 400° F., but poor behaviour at higher temperatures. It is well-known that additions of nickel to aluminium considerably increase its corrosion resistance in such environments, and Krenz[125] has explained that this improvement is due to the presence of a cathodic second phase changing the corrosion from grain boundary penetration to a uniform attack. This results in the formation of protective films, which are, however, rather brittle and may be damaged under certain conditions. Lobsinger and Atwood[126] have tested special aluminium alloys 1245 and M388, of which the compositions are not given, in high purity water up to 200° C. and found little difference in their performance. They note that the corrosion rate can be substantially reduced by lowering the *p*H of the water. Both Dlesk[127] and Binger and Marstiller[128] have reported on the use of aluminium for storing and handling high purity water, and both show that the metal is highly suitable for this service. Dlesk found that welds made in pure aluminium with aluminium-silicon filler alloys suffered slight pitting, while autogenous welds were unaffected after a year's service. Binger and Marstiller recommend that aluminium systems should be " conditioned " by contact with tap water before using for pure water, but Dlesk casts doubt on the efficiency of the procedure, and prefers pure water containing one part per million of ammonia.

In investigating the pitting of aluminium pans,

Aziz[129] measured the individual pit currents during cooking and storage of acid foods, and showed them to be more than ten times as great as in tapwater. This accounts for the perforation of thin pans, which may be avoided by not storing acid foods in pans after cooking. The work is a good example of scientific investigation confirming a conclusion reached long ago from practical experience. An account[130] of the corrosion of a cast aluminium-silicon (LM6M) alloy heat exchanger used with seawater describes three forms of attack, namely impingement cavitation, differential aeration corrosion due to a layer of silt, and electrolytic corrosion caused by the entry of copper in solution from brass studs and cover plates. This confirms the importance of avoiding mixed systems, as the last was the most damaging type of attack. A similar conclusion emerges from tests by Rowe[131] on a number of metal combinations with aluminium, including copper, brass and cast-iron, in tapwater with various corrosion inhibitors, such as might be used in radiator fluids. From this work, and tests in a simulated engine cooling system, Rowe concludes that a mixture of ethylene glycol and water inhibited with soluble oil, sodium nitrite and sodium mercaptobenzothiazole is suitable for use with a copper or an aluminium radiator.

Thompson and Lorking[132] have studied the properties of triethanolamine phosphate in glycol coolants, and show that copper ions produced by corrosion of the metal are stabilised as a blue cuprammine complex which, however, deposits on aluminium to cause localised corrosion. The inhibiting effect of hydrofluoric acid on corrosion of a number of metals by fuming nitric acid has been established by Mason, Taylor and Rittenhouse.[133] The metals included several aluminium alloys, notably even strong alloys with high contents of copper. Aluminium is so often the sufferer when galvanic corrosion occurs that it is quite a pleasure to find Ketcham and Beck[134] seeking an inhibitor to protect magnesium coupled to an aluminium alloy of H15 type. Magnesium vanadate, barium potassium chromate and calcium sulphide showed promise, and in combination were even more effective.

In 1957 the Corrosion Group of the Society of Chemical Industry held a symposium on the corrosion of metals in buildings. As regards non-ferrous metals, Jones[135] was given the task of emulating Dickens' fat boy, and right well did he make the flesh of his audience creep. However, the examples of corroded aluminium alloys to which he drew attention were susceptible of explanation, and were mostly due to such factors as mistaken applications, wrong alloy choice, or bad design. Laithwaite and Skerrey[136] described correct installation and choice of material in their contribution on aluminium cladding material, and gave examples of service experience covering periods up to half a century. The effect of concrete on metals was dealt with by Halstead,[137] who noted that, in general, wet concrete attacks aluminium, but the attack ceases after the setting period is complete, so long as the concrete is dry.

The effect of alkaline building materials on aluminium has been investigated by Walton *et al.*[138] They show by tests and performance in service that the metal corrodes only superficially, and the attack is self limiting, although under certain circumstances protection may be necessary. Asbestos cement products, although highly alkaline in reaction, do not cause serious attack of aluminium nails, and even magnesium oxy-chloride flooring compositions may be rendered safe by an addition of 1½% of potassium dichromate.

Walter[139] has stated that of about two hundred oil tankers fitted with aluminium alloy heating coils, on only four has there been damage to the tubes due to corrosion, and in these cases the trouble could be traced to inefficient cleaning. He emphasises the importance of removing waxy deposits from the tubes, as these are conducive to pitting attack, cracks in the wax leading to crevice corrosion. Rapid corrosion of seaside promenade railings[140] made from galvanised steel tube led a Kent resort to replace them by aluminium alloy scaffold tube, painted with aluminium paint. After nine year's service, these tubes are still in perfect condition, except for slight pitting, where the aluminium alloy is in contact with steel fittings, originally galvanised. Wright, Godard and Jenks[141] have carried out laboratory and exposure tests to assess the performance of an alloy similar to HE20WP when embedded in various timbers under marine conditions, and they find that the more acid woods cause the most attack. With all timbers, a coat of zinc chromate priming paint on the alloy almost completely prevented corrosion.

Two articles have appeared on corrosion in aircraft. Tate's[142] is a general summary and inevitably the reader wonders how any aircraft can possibly resist the thousand and one unnatural corrosive shocks that it is heir to ; but this is a tribute to the comprehensive scope of the paper. The benefits of regular cleaning are emphasised. Naval aircraft are exposed to particularly adverse conditions, but Chisholm and Rudd[143] find that a thin coating of butyl methacrylate lacquer has excellent adhesion to aluminium-clad aluminium alloy skins after pre-treatment with alcoholic phosphoric acid, and provides very good weather protection.

Stress corrosion is a particularly dangerous form of attack, leading as it may to catastrophic failure. Reinhardt[144] has quenched an aluminium-10% magnesium casting alloy (similar to LM10W) in cold water and in boiling water from solution treatment temperature, and found the material much less susceptible to stress corrosion when more drastically quenched. However, he recognises that this cold-water quench may introduce dangerously high residual stresses. Under certain conditions these might themselves lead to stress corrosion. Chadwick, Muir and Grainger[145] have tested aluminium-zinc-magnesium wrought alloys under direct-tension stressing and salt spray, and shown that ternary alloys with 5·7% zinc and 0·4–2·8% magnesium suffer from stress-cracking at comparatively low stresses. Additions of copper are beneficial, resulting in anodic areas at grain centres as well as at grain boundaries, while chromium elongates the grain structure and so diminishes stress-corrosion tendencies.

Butler[146] has studied the effect of lubricants, used in metal forming operations, on the finish of aluminium sheet. He shows that deforming sheet with unlubricated polished tools results in a high polish, but with increasing lubricant viscosity, surface appearance deteriorates rapidly. In a general resumé of the finishing of pressure die castings, of both aluminium and zinc alloy, Ruegg[147] describes grinding, sand blasting, barrel polishing, pre-treatment and painting, and also refers to the difficulties associated with the decorative anodising of pressure die castings.

Kape[148] has provided a very full account of the methods of producing thick anodic films on aluminium alloys in various acids and acid mixtures, with particular reference to a method based on constant wattage power input. He also describes at length the properties of the films produced, including their resistance to corrosion and abrasion. The increasing interest in the use of anodised aluminium in buildings has been reflected in a number of papers; Brace[149] explains that for long-term durability coatings of adequate thickness are essential, and recommends 0·001 in. for use in permanent buildings. He points out that few of the colours used for dyeing such films are truly permanent; grey, gold and bronze complete the list, but several other colours are known to persist for five to ten years. While agreeing as to optimum thickness, Hanstock[150] is perhaps a little more sanguine as to colour fastness, stating that yellow, blue and black may be used with some confidence. Both authors emphasise the prolongation of life of anodic finishes outdoors that may be ensured by regular cleaning.

Another promising field of application of anodised aluminium is motor-car trim, and Fenn[151] has summarised the materials used, the methods of brightening and anodising and the finishes that they provide. This author rightly stresses that bright details made from super-purity metal are only the first stage in the development of aluminium trim. Brace[152] refers specially to this field of application in his statement on the effect of alloy composition and structure on response to electrochemical and chemical brightening and anodising, and explains the relative difficulties of applying these finishes to the various wrought forms and to castings, these last presenting problems still largely unsolved. A paper on chemical brightening was also read by the same author[153] to the Sixth Mechanical Engineering Congress in Paris.

Some mention of exterior architectural finishes is made by Smith and Shaw[154] in their article on decorative finishes, but they are concerned chiefly with the more familiar teapots, cosmetic containers, cocktail shakers and the like that represent the greatest volume of decorative anodising at present. In a different class are the opaque finishes resulting from chromic acid anodising; Brace and Peek[155] have described this technique, unfamiliar in this country but offering attractive finishes contrasting with the reflective type provided by brightening and sulphuric acid anodising. Preliminary guidance has been given on the choice of aluminium alloy,[156] wrought or cast, for anodising, but the importance is emphasised of consultation with both material supplier and anodiser. Again, reference is made to difficulty in decorative anodising of pressure die castings, but it is stated that flow lines may be avoided by careful design of casting and of die.

During the period of scarcity and high price of copper, interest in the electrical applications of aluminium naturally quickened, and special methods of insulating wire and strip were developed. Richaud[157] has described a French process of continuous anodising and impregnation with varnish of aluminium wire and strip, and listed the electrical properties of the coating produced, and also its flexibility and temperature resistance. A similar process used in Britain has been discussed by Bramley and Pullen,[158] but in this case the anodic coating alone is relied upon for insulation, so that the wire produced may be used electrically at temperatures as high as 300° C., a considerable advantage in windings.

Anodic coatings produced by very high current densities in refrigerated electrolytes have valuable abrasion resisting properties, and a proprietary process for conferring hard anodic finishes has been described.[159] Examples of the use of such finishes are listed, including aircraft turbine rotors, railway buffers, textile equipment, and ball-race housings, and it is claimed that the process is applicable to all the wrought alloys of aluminium, and most casting alloys. This and other methods of providing hard finishes on aluminium have been compared,[160] including hard plating and sprayed coatings of fused oxides, as far as their appearance, abrasion resistance, hardness, adhesion, electrical resistivity, corrosion resistance and certain other properties are concerned, and the relative costs are stated. Typical applications are also given. The flame spraying of refractory coatings[161] on aluminium provides thermal protection, but wear resistance is also much improved. One limitation of such coatings seems to be their slight porosity, so that in extended periods of service corrodants may penetrate to the base alloy.

Introducing an article on the vitreous enamelling of aluminium, Todd[162] refers to this as a new finish actually considerable work was done in this country nearly a decade ago on such finishes, and the porcelain enamelling of aluminium is well established in the U.S.A. However, it is very encouraging to learn that a company in this country is now manufacturing frits for aluminium, and to have an account of techniques and applications. A call is made for special furnaces suitable for the low firing temperature as compared with ferrous metals. The company concerned recently held a refresher course largely devoted to the enamelling of aluminium at which Guy[163] described the milling of the frits, Vaughan[164] the firing procedure, and Symonds[165] the applications of the enamels by spraying, dipping or brushing. Some information is given on the testing of coatings. Biddulph[166] has also given an account of the vitreous enamelling of aluminium. He mentions fusing temperatures of 530–550° C., so that with some alloys great care is necessary in jigging and supports.

Although certain applied finishes will stick efficiently to a degreased aluminium surface, with most paint systems a reliable pre-treatment is necessary to avoid the danger of poor adhesion. In reviewing the pre-treatment of metal surfaces generally, Lewis[167] considers the well-known proprietary treatments used on aluminium, including phosphates, alkaline chromates and acid chromates, and mentions anodising. This last is often used as a base for paint on aircraft, and is efficient but very expensive for such a purpose. Accordingly, the surface of the new Vickers "Vanguard" aircraft[168] is to be pre-treated by the Alocrom process, and specially large tanks for this treatment have been installed. The dangers of mercury-containing anti-fouling paints on aluminium hulls are now well-known, but West[169] has recalled examining a 25 ft. day cruiser during the war that had had such paint applied, resulting in very severe local corrosion of the aluminium alloy hull below the water line. West suggests that in such cases the mercury would probably be most readily removed by the careful and controlled application of heat from an oxy-gas blowpipe.

Much aluminium is used in the protection against

corrosion of other metals. Ingham[170] has considered aluminium sprayed on steel as a base for paints, and described the correct surface preparation and method of spraying. He recommends that only a thin coat be used when paint is to be applied, as this is sufficient to prevent the chief cause of paint failure, namely rusting at the interface. There has been a good deal of recent controversy regarding the mechanism by which sprayed aluminium protects steel, and Mayne and Van Rooyen[171] have presented their views, based on experiment. They give evidence that the whole of the sprayed aluminium is in metallic contact with the steel, and that in sea-water immersion the aluminium is attacked sufficiently rapidly to provide cathodic protection. In tap water, on the other hand, the aluminium was not rapidly attacked and the protection is thought to be due to blockage of the pores in the sprayed coating.

The production of aluminium powders and pastes[172] based on them has been described, and the article covers history, applications, paint formulae, and the testing and evaluation of the product.

Applications

The marine applications of aluminium alloys continue to attract considerable attention, so that the entry into service for the Norwegian America line of the motor ship *Bergensfjord* was an important event. Haug[173] has described the design and construction of the ship, whose all-welded aluminium alloy superstructure is believed to be the largest of its type hitherto completed. It incorporates 410 tons of aluminium-magnesium alloy plate and sections, and 400,000 ft. of welds using 334 miles of wire. The motor cargo liner[174, 175] *Elmina Palm*, built by the same company as the *Bergensfjord*, has to operate in West African rivers with severe draught restrictions. The whole of the structure above the bridge deck is in aluminium alloy, consumable electrode welded, and a weight saving of 63% was achieved. The ship also has aluminium coils for heating its fuel tanks, and portable aluminium hatch boards. An interesting feature of the cargo motor ship *Kepwick Hall* is a deep-tank hatch cover[176] on its second deck, which spans an opening of 22 ft. by 15 ft. 9 in. This cover would have weighed over 5 tons in steel, but by making it in welded aluminium alloy this was cut to under 2 tons.

Two former cargo ships have been converted into passenger liners[177] and re-named *Mariposa* and *Monterey*, and a good deal of aluminium alloy was used in the transformation. The shower enclosures were made from aluminium alloy sheet by inert gas metal-arc welding. Nigerian fishermen operate principally in dug-out canoes, as from time immemorial, but successful tests have been made of a 20 ft. welded aluminium alloy fishing boat[178] to augment these resources. The breakers regularly encountered are as high as 5 ft., so that construction must be robust.

Service experience on the Toronto underground with both aluminium and steel coaches has enabled Bardsley[179] to compare the economics of the two types. Savings are noted in power consumption, and improved life of bearings, wheels and bodies with the light coaches, and it is concluded that the extra cost of aluminium construction is more than justified. The first fifty welded aluminium alloy box car doors[180] made in the U.S.A. have gone into service with the Pennsylvania rail road, and their performance will be observed with a view to extension of the application. Also from the U.S.A. comes news of a pressure die cast aluminium alloy integral car wheel, hub and brake drum[181]; mechanical tests indicate that this wheel is far above the accepted standard for steel wheels in both brake performance and durability. An interesting application of pressure die castings is in a taximeter[182]; these are in use abroad as well as in this country, so that provision is made for such phrases as "Prix à Payer" as well as the more familiar one. Gravity die castings have been used in the construction of the Ricardo positive displacement supercharger,[183] the alloy being of LM16-WP type. Newell[184] points out that although aluminium honeycomb sandwich construction is perhaps best known in aircraft, it may be applied also to boats, motor cars, textile machinery, and in other industries.

Turning to the building field, a new solution has been provided to the problem of inexpensive ventilation of corrugated sheet roofs. Standard size aluminium alloy corrugated sheets are now available with louvres[185] pressed at either 6 in. or 12 in. centres, thus affording exits for steam or fumes while maintaining the roof completely rainproof. A new design of sash window[186] in aluminium alloy has been announced, which uses stainless steel springs in the place of weights and cords, and provides an unusually high degree of weather tightness. Curtain walling with several different materials continues to expand rapidly, and one variety based on special aluminium alloy extrusions with aluminium windows has been described,[187] with illustrations of its incorporation in buildings in this country and abroad. Aluminium panels[188] find considerable application in industrial buildings, and the walls of a very large aluminium producing and fabricating plant in the U.S.A. consist of inner and outer sheets of corrugated aluminium with a core of glass fibre insulation. Six men were able to install this siding at a rate of 1,920 ft./day. An interesting building recently constructed in this country is a new warehouse[189] at Woking, which has aluminium roof structure and decking, with aluminium roof lights. The eight principal aluminium alloy trusses span almost 208 ft. supported by reinforced concrete columns.

Aluminium has always been attractive for domes, the Dome of Discovery at the 1951 Exhibition being perhaps the best known. A stressed-skin dome[190] erected at Hawaiwan Village in Honolulu weighs only 39,000 lb., but provides seating capacity for 1,800 to 2,000. It is bolted together from diamond shaped panels varying in length from 9 to 11 ft. The welding of aluminium alloys has invaded the structural as well as the marine fields, and what are claimed to be the first all-aluminium, welded mill-type cranes[191] have been installed at a factory in the U.S.A. Capacity is from 25 to 35% greater than steel cranes with comparable wheel loads. A footbridge[192, 193] of 60 ft. span has been constructed from aluminium alloy HE30-WP by consumable electrode welding to cross the River Ebbw between Bassaleg and Rogerstone in South Wales. Much has been heard recently of radio telescopes, principally because of the activity of the Jodrell Bank instrument in Sputnik tracking; a smaller type, but nevertheless with reflector 45 ft. in diameter,[194] has been made for the Royal Radar Establishment at Malvern. Both structure and sheeting

of the reflector are of aluminium, and only ± 1 in. of deviation from true paraboloid was permitted.

Elliott[195] has summarised the packaging applications of aluminium, which account for something approaching 10% of the output of semi-fabricated forms in this country. One important branch of the aluminium container industry is that devoted to aerosols,[196] and the manufacture, filling and uses of these pressure dispensers have been described. Another quite recent packaging development is the foil container,[197] and methods of making these and improvements in their design form the subject of an article on examples seen at an American exhibition. The most important announcement in 1957 regarding the use of aluminium in packaging concerned the agreement in America between an aluminium producer, a can manufacturer, and an oil company involving the supply of aluminium quart cans[198] for retail sale of motor oil, with special arrangements for collection of the scrap cans. A new development in materials handling is the use of tote bins[199] made from aluminium alloy in three standard sizes of 42, 74 and 110 cu. ft.

Economics are a delaying factor in the development of aluminium pipe lines, but in certain circumstances a particular advantage of the metal ensures its use. In the case of a gas-carrying line[200] in Texas, 8 in. in diameter and 20,000 ft. long, corrosion resistance was the deciding property. The uses of aluminium in the Dounreay materials testing reactor[201] have been described, including the construction of the fuel elements and their containing tank. The modern concrete lamp standard has the same effect upon some architects as a red rag to a bull, and the development of aluminium lighting columns seems a likely soothing influence. Some examples, and also the other uses of aluminium in street lighting,[202] have been described. In 1957 the Aluminium Development Association held a successful and well-attended symposium on aluminium in electrical engineering; the papers and discussion will shortly be published. An introductory paper by West[203] has already appeared in a technical journal, and deals with the economic aspect, from the point of view of metal costs, outputs and ore resources and reserves.

Every housewife knows the value of aluminium in the kitchen, and this applies also to industrial catering, as Elliott[204] has recounted.

That excellent novel "The Gun" by C. S. Forrester, has been filmed, under the title "The Pride and the Passion." The gun[205] that is the true hero of the piece was cast in aluminium, in order to facilitate handling. This is, of course, strictly anachronistic, as the story deals with the Peninsular War, but no doubt the actors who had to drag the cannon blessed Humphry Davy, Hans Oersted, St. Claire Deville, Karl Bayer, Charles Hall, old uncle Paul Héroult and all.

Standards

The logical step following research and development is standardisation, and the tremendous expansion of the aluminium industry nationally and throughout the world is reflected in the publication of standards both for the metal itself and for applications into which it enters. The task of listing the standards for wrought light alloys published by various countries[206] has been continued, those of India and Switzerland being added to the collection. In a concluding section, some comparison has been made of the various standards, as regards designations, compositions and their presentation and identification marking, but no comment is made from the metallurgical viewpoint. Two valuable tables are given, one summarising standard alloys of approximately similar compositions from various countries, and the other giving these standard compositions, enabling comparisons to be made.

In the middle of the year an article appeared listing all current specifications[207] covering light alloys. This is useful for reference, but contains a few inaccuracies; for instance, the temper designation of B.S. 1470–1477 quoted are not the current ones, and B.S. 1490 is referred to as amended instead of revised. But these are minor criticisms of a good paper.

Two more standards covering aluminium for electrical purposes have been published during the year. B.S. 2898[208] is concerned with pure aluminium, E1E, and an aluminium-magnesium-silicon alloy, E91E as bars, rods and sections. E1E is standardised in the M and ½H conditions, and E91E fully heat-treated WP. Drawn strip[204] D1E, annealed, half-hard and hard is covered by B.S. 2897, and both standards have requirements for electrical conductivity as well as mechanical properties. Although both documents were issued on the same day, each refers to the other as already published—an almost Gallic declining of precedence. The great increase in use of corrugated aluminium sheets[210] had led to the issue of B.S. 2855, which covers alloy dimensions and profile. It ensures the interchangeability of sheets by putting limits on the variation of distance between the crowns of outside corrugations.

The valuable work has continued of the B.S.I. Committee preparing standard referee methods of analysis of aluminium alloys,[211] and sections have been published dealing with manganese by two methods and with iron. B.S. 2851 standardises aluminium alloy sputum mugs principally for hospital use. The material is commercial purity aluminium, and reference is made to B.S. 1470, but, unfortunately, to the 1948 issue, now superseded by the 1955 revision. This seems to reinforce the argument that when a British Standard refers to another, the date of issue should be omitted, and the principle established that the latest revision is always meant. Turning from a small to a large container, a standard for aluminium alloy refuse skips[212] has been published. These are the dustbin-shaped containers into which the dustman tips the contents of the domestic refuse holder, in order to carry them to the dustcart. The merits of lightness in this application are obvious and the eventual scrap value of the skip is an added attraction.

British Standard recommendations for gas welding aluminium and its alloys, first issued in 1943, have been revised.[213] This standard is advisory rather than mandatory; its operative word is "should" in place of the more familiar "shall." In the view of at least one reader of specifications, the Institution would be well advised to restrict the ordinary list of British Standards to the mandatory type, and create to replace B.S. 1126 and similar documents a new series, call them codes of practice or what you will; this would avoid confusion and help to crystallise the aims of various standard documents in the mind of the technical public.

Another British Standard in the welding field has been

revised, namely that dealing with filler rods for gas welding,[214] and the section on aluminium covers four grades of pure metal and six alloys. A new standard is concerned with filler rods for gas-shielded tungsten arc welding,[215] which are the same in composition as those for gas-welding with the addition of the aluminium-2½% magnesium alloy. D.T.D. 5070 has been issued, for an aluminium-clad fully heat-treated heat resisting alloy[216] in the form of sheet and strip.

It is a pleasure to record the official withdrawal of the B.S. STA 7 "Services Schedule of Non-Ferrous Metals and Alloys, Group 6, Aluminium and its Alloys." This document has been an unconscionable time dying, but now, at last, it is dead. For this relief, much thanks.

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In the New Year Honours List

KNIGHTHOOD

A. T. Barnard, C.B., O.B.E., Director-General of Inspection, Ministry of Supply.

W. R. J. Cook, C.B., Deputy Director, Atomic Weapons Research Establishment, Aldermaston, United Kingdom Atomic Energy Authority.

C. K. Ingold, Professor of Chemistry, University College, London.

W. J. Worboys, Chairman, Council of Industrial Design; Director, Imperial Chemical Industries, Ltd.; Vice-President, Associated British Chemical Manufacturers.

K.C.B.

H. W. Melville, Secretary, Department of Scientific and Industrial Research.

C.B.

J. C. Blake, Solicitor and Legal Adviser, Ministry of Health and Ministry of Housing and Local Government.

H. Constant, C.B.E., Director, National Gas Turbine Establishment, Ministry of Supply.

J. E. Serby, C.B.E., Director-General, Guided Weapons, Ministry of Supply.

K.G.B.E.

Sir Harold E. Yarrow, Bt., C.B.E., Chairman and Managing Director, Yarrow and Co., Ltd.

K.B.E.

M. E. Adams, O.B.E., Civil Engineer-in-Chief, Admiralty.

N. A. Gass, C.B.E., M.C., Chairman, British Petroleum Co., Ltd.

C.B.E.

E. H. Ball, Managing Director, The British Thomson-Houston Co., Ltd.

A. Barraclough, Office Manager, English Electric Export and Trading Co., Ltd., New York.

C. R. Burch, Warren Research Fellow in Physics, University of Bristol.

A. E. Crook, Principal Inspector of Mechanical Engineering, Mines Inspectorate, Ministry of Power.

H. J. Emeleus, Professor of Inorganic Chemistry, University of Cambridge.

C. H. Johnson, Director, Materials and Explosives Research and Development, Ministry of Supply.

H. T. Johnson, O.B.E., Deputy Director of Naval Construction, Admiralty.

J. A. Mason, M.M., Manager and Director, Automatic Telephone and Electric Co., Ltd.

C. Metcalfe, Managing Director, E.M.I. Electronics, Ltd.

R. W. West, Principal, Battersea College of Technology.

O.B.E.

S. Alty, Works Manager, Brine and Water Works, Alkali Division, Imperial Chemical Industries, Ltd.

L. R. E. Appleton, Chief Engineer (Weapons Division), The Fairey Aviation Co., Ltd.

G. F. Brown, Director, Cottage Laboratories, Ltd.

N. Carter, Chief Naval Architect and Technical Manager, Swan Hunter and Wigham Richardson, Ltd.

W. J. Challens, Senior Superintendent, Weapons Electronics, Atomic Weapons Research Establishment, Aldermaston.

V. F. Dorey, Principal Examiner, Patent Office, Board of Trade.

Lieut.-Col. E. N. Elford, T.D., Manager, Radar Division, Marconi's Wireless Telegraph Co., Ltd.

H. C. Fitzer, Superintending Electrical Engineer, Admiralty.

J. F. Gillies, Vice-Principal Belfast College of Technology.

L. R. Greenaway, Superintending Civil Engineer, Admiralty.

R. A. F. Hammond, Principal Scientific Officer, Armament Research and Development Establishment.

The Hon. C. A. Hankey, Senior Technical Officer, Ministry of Labour and National Service.

S. A. Hunwicks, Senior Principal Scientific Officer, Royal Aircraft Establishment.

V. J. M. Kendrick, Civil Assistant to Senior Superintendent, Royal Ordnance Factories, Woolwich.

C. D. Lawrence, Superintending Scientist, Central Dockyard Laboratory, H.M. Dockyard, Portsmouth.

R. A. McMahon, Secretary, British Electrical and Allied Industries Research Association.

J. O'Hagan, General Secretary, National Union of Blastfurnacemen, Ore Miners, Coke Workers and Kindred Trades.

E. J. Richards, Professor of Aeronautical Engineering, University of Southampton.

E. G. Rowe, Chief Valve Engineer, Standard Telephones and Cables, Ltd., Sidcup.

H. Seligman, Deputy Chief Scientist, Head of Isotope Division, Harwell, United Kingdom Atomic Energy Authority.

S. H. Smith, Finance and Accounts Officer, Department of Scientific and Industrial Research.

W. Swift, Director and Deputy General Manager, Joseph Lucas Gas Turbine Equipment, Ltd.

A. Sykes, Technical Director, David Brown and Sons (Huddersfield), Ltd.

M.B.E.

H. Annis, Chief Inspector, Metropolitan-Vickers Electrical Co., Ltd.

J. A. Barber, Contracts Manager, J. & H. McLaren, Ltd.

W. L. Bower, Chief Designer, James Neill and Co. (Sheffield), Ltd.

Lieut.-Commander (A) J. Brandt, D.F.C., R.N.R., Civilian Ferry Pilot, Royal Naval Ferry Flight, Short Brothers and Harland, Ltd., Rochester.

E. F. Burford, Manager, Heavy Construction Department, G. A. Harvey and Co. (London), Ltd.

A. J. G. Cook, Senior Technical Superintendent, No. 20 Maintenance Unit, Royal Air Force, Aston Down.

F. M. Evans, Chief Diesel Designer, C.A.V., Ltd.

W. Hardy, Electrical Engineer, Admiralty Gunnery Equipment Depot, Coventry.

S. F. Hathaway, Senior Experimental Officer, National Physical Laboratory.

J. W. Heath, Chief Draughtsman, Admiralty.

G. Hollingsworth, Assistant Manager, Steel Production, Arthur Balfour and Co., Ltd.

T. Hughes, Chemist II, Royal Ordannce Factory, Pembrey.

E. H. Ker, Assistant to the Motive Power Superintendent, Eastern Region, British Railways.

J. K. Lightfoot, Works Superintendent, The English Electric Co., Ltd.

Major W. T. McQuillen, Senior Lecturer, Science Department, Royal Military Academy, Sandhurst.

J. Mather, Workshop Manager, Atomic Weapons Research Establishment, Aldermaston, United Kingdom Atomic Energy Authority.

W. H. Minnitt, Mechanical and Electrical Engineer, Air Ministry.

E. L. Newport, Manager, Development Fitting Shop, Bristol Aero-Engines, Ltd.

G. Newrick, Engineer III. Royal Ordnance Factory, Blackburn, Ministry of Supply.

G. McGregor Perry, Assistant Manager, Electrical Department, Harland and Wolff, Ltd.

J. Rutherford, Foundry Manager, Wm. Beardmore and Co., Ltd.

T. W. Shields, Superintendent, Fitting and Assembly Shops, Baker Perkins, Ltd.

N. J. Silveston, Assistant Warship Production Superintendent, Southern Area, Admiralty.

Miss I. M. Slade, Information Officer, British Iron and Steel Research Association.

F. W. Smith, Superintendent, Boiler Shop, J. I. Thorneycroft and Co., Ltd.

F. A. Soward, Works Engineer, E. N. Mason and Sons, Ltd.

C. F. Stacey, lately Senior Experimental Officer, Ministry of Supply.

W. R. Sutherland, Chief Draughtsman, Parsons Marine Engineering Turbine Research and Development Association.

J. E. Thwaites, lately Senior Executive Engineer, General Post Office.

B. Trewhitt, Shipyard Manager, William Doxford and Sons (Shipbuilders), Ltd.

J. O. C. Wheelans, Production Engineer, Valve Making Department, Mullard Radio Valve Co., Ltd.

H. B. Wiggins, Higher Executive Officer, Risley, United Kingdom Atomic Energy Authority.

D. V. Young, Civil Defence Controller, Birmingham Small Arms Company, Ltd.

B.E.M.

T. Barthorpe, Skilled Turner, William Jessop and Sons, Ltd.

C. L. Beech, Foreman, British Chrome and Chemicals, Ltd.

(*Continued on page 98*)

General view of the new mill.

New Double-Duo Bar Mill

Brightside Installation for Sanderson Brothers & Newbould, Ltd.

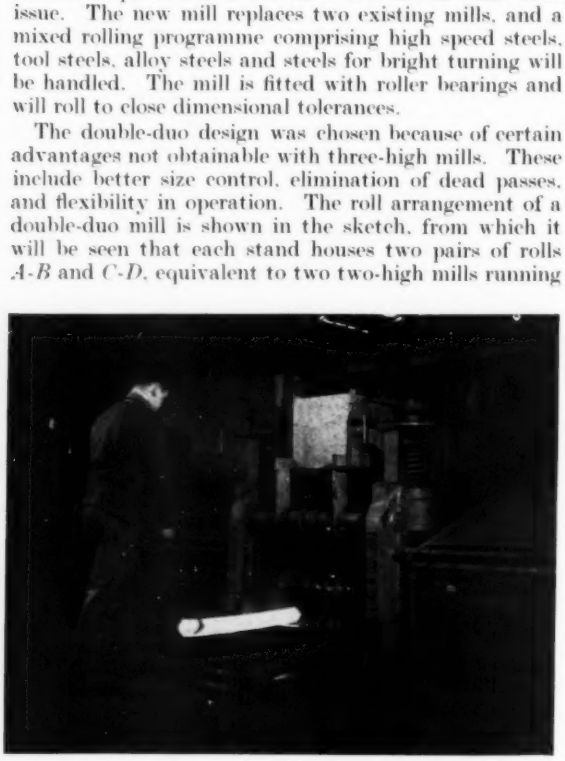
AS part of their general modernisation programme, Sanderson Brothers and Newbould, Ltd., have recently brought into operation at their Attercliffe Steelworks a new 10½ in. double-duo bar mill made by The Brightside Foundry and Engineering Co., Ltd. This follows on the modernisation of the adjacent heat treatment plant which was described in our June 1955 issue. The new mill replaces two existing mills, and a mixed rolling programme comprising high speed steels, tool steels, alloy steels and steels for bright turning will be handled. The mill is fitted with roller bearings and will roll to close dimensional tolerances.

The double-duo design was chosen because of certain advantages not obtainable with three-high mills. These include better size control, elimination of dead passes, and flexibility in operation. The roll arrangement of a double-duo mill is shown in the sketch, from which it will be seen that each stand houses two pairs of rolls *A-B* and *C-D*, equivalent to two two-high mills running in opposite directions. The bar enters through rolls *A-B* and is returned through rolls *C-D*, which are so arranged that the bar can emerge without fouling roll *A*. An obvious advantage of this arrangement is that wear on the top and bottom rolls of each pair will tend to be even, as compared with the three-high mill in which wear on the middle roll is twice that on the top and bottom rolls.

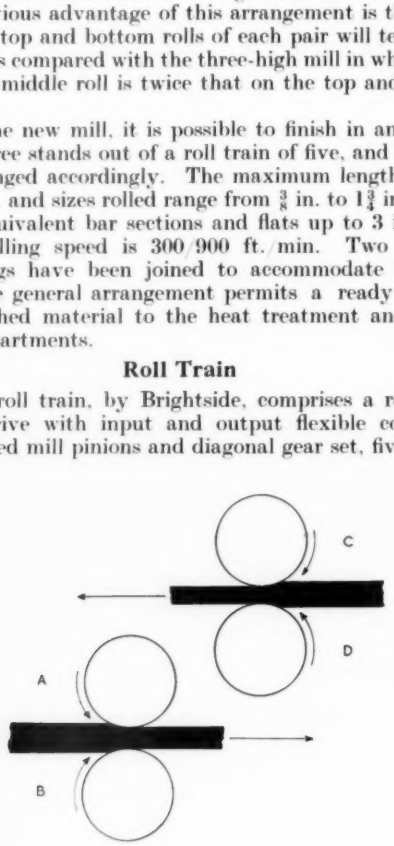
In the new mill, it is possible to finish in any of the last three stands out of a roll train of five, and the floor is arranged accordingly. The maximum length of bars is 60 ft. and sizes rolled range from ⅜ in. to 1¾ in. round and equivalent bar sections and flats up to 3 in. wide. The rolling speed is 300/900 ft./min. Two existing buildings have been joined to accommodate the mill and the general arrangement permits a ready transfer of finished material to the heat treatment and bright bar departments.

Roll Train

The roll train, by Brightside, comprises a reduction gear drive with input and output flexible couplings, combined mill pinions and diagonal gear set, five stands

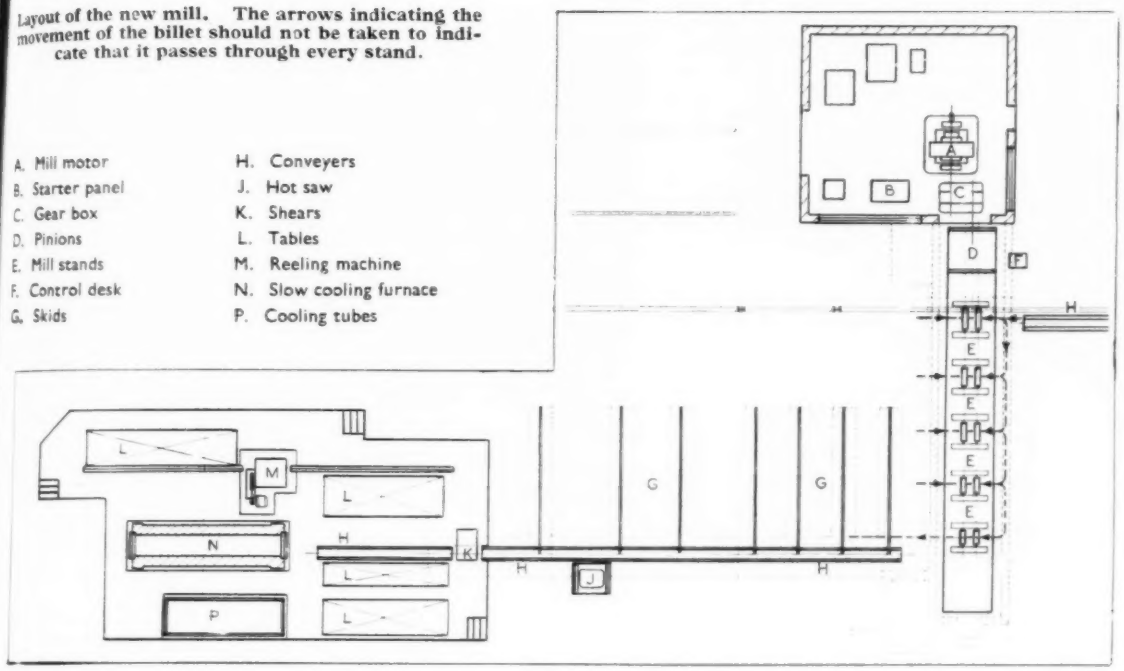


Roughing stand: note the cooling water tank above the rolls.



Roll arrangement of double-duo mill.

Layout of the new mill. The arrows indicating the movement of the billet should not be taken to indicate that it passes through every stand.



of double-duo roll housings, and universal type mill couplings. Provision is made for the installation of a sixth stand of rolls if desired. The roll housings are of Hitest cast iron, fitted with cast steel chocks and roller bearings. The top rolls and their chocks are balanced by springs and suspension bolts, adjusted vertically by forged steel screws operated by swivel levers and notched discs.

A supply of river water for cooling the rolls is provided by a Worthington-Simpson Monobloc pump capable of delivering 400 gal. min. Tanks are fitted on each housing, the water level being controlled by a ball-operated valve in each tank. Water from these tanks is directed on to the rolls by flexible coolant hose, carrying the scale through a scale pit into a collecting pit, which can be cleared as required.

To facilitate roll changing, spare housings are provided to enable two complete stands of rolls to be prepared whilst the mill is in operation. The housings are transferred to the mill from the housing assembly bed by a Shelvoke and Drewry heavy duty fork lift truck. The roller bearings are fitted into the rolls by means of oil injection in a dust free fitting shop and roll store.

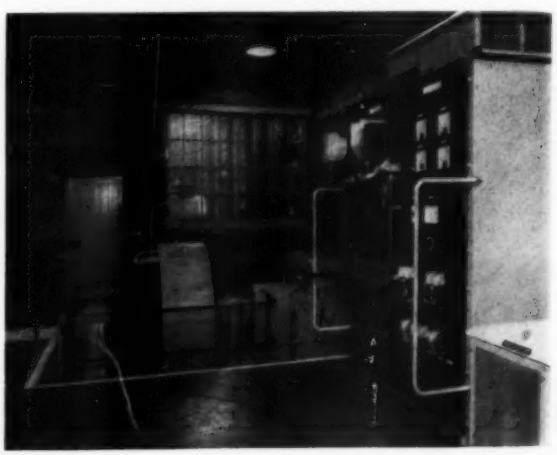
Electrical Equipment

Electric power supplied by The Yorkshire Electricity Board is taken from a works sub-station by means of an 11kV. feeder to a transformer feeding a steel tank rectifier giving an output of 420kW. at 500 V. D.C. This, in turn, passes through appropriate control equipment in the mill sub-station to the 500 h.p. 500 V. 300/900 r.p.m. D.C. mill motor. The mill is normally started by the sub-station attendant, whose duty it is to run the mill motor up to its minimum speed of 300 r.p.m. Afterwards, speed regulation is in the hands of the mill supervisor. A control desk is provided adjacent to the roughing stand, equipped with a load-indicating ammeter, speed control regulator and meter, and an emergency stop button. The motor is provided with dynamic braking. The English Electric Co., Ltd., supplied the electrical equipment, which was installed in the sub-station by Electric House (Denton), Ltd.

Mill Ancillaries

For the time being, billets are being heated in a continuous-type pulverised fuel fired furnace which served the previous 10 in. mill. To maintain production, this mill has been kept in operation during the building of the double-duo mill, but once the latter is in full operation, the old mill and its steam engine will be dismantled and additional billet furnace capacity added.

Live roller gear is provided for the transmission of



Mill motor and control panel.

billets from the furnace to the roughing stand, and hot cogging shears are installed adjacent to the roughing stand for use when required. As already stated, bars can be finished in any of the last three stands, and live roller gear is provided to carry the finished material to the hot saw or shears. Power-operated transfer gear fitted on the outgoing side of the mill, to move bars from the last three stands across the floor to the live roller gear, comprises seven chain type skids. George Robson (Conveyors), Ltd., were responsible for the roller gear and transfer skids. The Clifton and Baird hot saw is fitted with a 36 in. blade of Sanderson's own manufacture, and the saw pendulum is actuated by self-contained hydraulic mechanism by Hele-Shaw. The hot shear as at present installed is an existing unit that has been adapted for the purpose but this will subsequently be replaced by a shear of Mubea manufacture capable of cutting bars up to a maximum size of 2 in., round or square.

On leaving the hot shear or saw, bars pass on to an outgoing live roller table, from which bars and flats not requiring slow cooling or reeling are transferred to a straightening rack to be removed subsequently by overhead crane. Bars for reeling are transferred to a second rack and from thence to the Platt hot reeler. After reeling, they are passed into a loading and storage rack.

Bars requiring furnace cooling are charged into a town's gas fired, temperature controlled, slow cooling furnace, positioned opposite the end of the live roller conveyor from the shears. Other material for retarded cooling can be passed into a nest of slow cooling tubes, which are surrounded by insulating powder and cased in.

Finished bars are removed by overhead crane to a despatch section at the end of the mill. Those requiring hardening and tempering, normalising or annealing, are placed on stillages arranged at the side of the bay in the finishing section, from which they are picked up by the revolving charging machine in the adjacent heat treatment department and charged direct into the furnaces.

Finishing end of mill showing slow cooling furnace, with insulated cooling tubes on left and hot reeler on the right

General view of the heat treatment plant.

The mill floor and finishing section are served by a newly installed 3-ton electric overhead travelling crane by Carruthers. An existing overhead crane already serves the despatch section and an 8 in. mill which for the time being will continue to operate in this part of the bay.

Heat Treatment

The modernised heat treatment plant, which has been in operation for about three years comprises two hardening furnaces and a tempering furnace, an oil quenching unit, a water quenching unit, and a revolving floor-type charging machine. The furnaces, designed and installed by Fuel Furnaces, Ltd., have working chambers 5 ft. wide × 1 ft. 9 in. high × 16 ft. 6 in. long, and are capable of treating a charge of up to 3 tons. The proportional gas-air control system is used, the thirty burners being divided into two zones, front and rear, with a pyrometer to record the temperature in each. A control panel carries the six Kent Multelec temperature recorder-controllers and ancillary equipment.

Metal Forming Film

THE world's output of metal is 350 million tons a year. Almost all of it goes through a forming process—pressing, rolling, or extruding—from ingots or billets. Metal forming is made possible by the plasticity of metals, which is their ability to change shape under pressure. The new Shell Film Unit film, *Forming of Metals*, which was photographed at works throughout Britain, deals with all the main forming processes. Photomicrographs and models are used to describe some of the processes and to demonstrate how the metal is given particular physical properties.

The film, which is in colour and runs for 28 minutes, was directed by Peter de Normanville and photographed by Sidney Beadle and Eric Chamberlain. Enquiries about showing the film should be addressed to Shell-Mex and B.P., Ltd., Shell-Mex House, Strand, London, W.C.2.

Instrumentation for Large Turbo-Blower

Kent Installation at Scunthorpe

THE bringing into service of the world's largest steam-driven turbo-blower sees the completion of a scheme which additionally called for the largest Dall flow-tube that George Kent, Ltd., have yet manufactured, as well as for special instrument-flexibility requirements. At the Scunthorpe Works of the Appleby-Frodingham Steel Company, it became necessary to provide an increase in blowing capacity for each of their four "Queen" blast furnaces in order to increase production of pig iron. The answer to this problem has been to construct a large blower to augment the output of the other four, and at the same time to act as a stand-by during maintenance periods. This new turbo-blower constructed by Messrs. C. A. Parsons & Co., Ltd., and known as E blower, is capable of delivering 160,000 cu. ft. of free air per minute, at a pressure of 35 lb. sq. in.

Before E blower came into operation, the total blast-air required by the furnaces was supplied by the four smaller turbo-blowers, A, B, C and D, each of 80,000 cu. ft. of free air per minute capacity, at a pressure of 30 lb. sq. in. Each of these blowers discharges into a separate four-branch manifold, fitted with the necessary isolating valves, so that any one blower unit may be connected, via the appropriate blast main, to any one of the four blast furnaces.

The operation of the plant is of necessity very flexible, in order that maximum safeguard against shutdown can be given. Like the other four blowers, E blower discharges into a four-branch outlet manifold, so that it also may be coupled to any one of the four blast furnaces. In the mode of operation using E blower, any particular furnace can receive its air in one of three ways:

(*a*) From one of the four blowers already existing, as originally intended.

(*b*) From one of the four blowers with the extra air to obtain higher production supplied from the large make-up blower. This is referred to as "split-wind blowing."

(*c*) From the large blower (E) only. In this connection, it was also decided that E blower would be capable of blowing two furnaces at any time, and the eventual design-rating established it as the largest steam-driven blower in the world.

Any of these three working arrangements can be obtained, the blowers employed and the furnace to which they are coupled being selected by the positioning of isolating valves in the branch manifolds. The amount of air supplied to each furnace by E blower can be varied by remote adjustment of flow regulating devices, which operate hydraulically controlled butterfly valves situated one in each main, just downstream of E-blower outlet.

In a plant of this nature, it is essential that the furnace operators know how much air is being supplied by each blower unit. The many combinations of the system that may be employed, and the great distances involved, necessitate the use of a telemetering scheme that is capable of being interswitched so as to correspond to any particular blower arrangement, yet still retain a high degree of accuracy. The over-all accuracy limits within which this scheme is designed to work—including transmitters, summators, receivers and switches, as well as the normal instrument and primary-element accuracies—is $\pm 4\%$ from maximum down to half-scale reading, then falling gradually to $\pm 6\%$ below this figure. The rate of air flow passing through each of the four 54-in. diameter mains on the outlet of E blower is measured by a Kent RTE ring-balance instrument, the differential-pressure-producing primary element for which is a low-head-loss fabricated mild-steel Dall tube. Temperature and pressure are also taken from each main, so that the final reading gives the pressure- and temperature-corrected flow reduced to N.T.P. The pressure varies over a range normally of 28–35 lb. sq. in., and a Bourdon-tube transmitter is used. Temperature variations over a range of 150°–400° F. are measured and transmitted by a Multelec potentiometric indicator working with a Chromel-Alumel thermocouple. The head transmitter (electric) is a 25-in. w.g. Kent Commander mercurial U-tube instrument. Signals from the three transmitters are then fed into a circuit which produces the final reading of the rate of flow.

The pressure transmitter is fitted with a special former

Courtesy of the Appleby-Frodingham Steel Co. (Branch of the United Steel Cos., Ltd.)
E turbo-blower.

to extract the square-root law ; for the Multelec potentiometric indicator the position of the feeler is adjusted on the re-transmitting slidewire by a cam-operated mechanism, so that temperature non-linearity is corrected. This automatic compensation for both pressure and temperature is very important, because the remote registration at blast furnace and cast house is the result of summating the output of individual blowers, plus the amount of air being blown from E blower as a reinforcement. Consequently, the two flows must be referred to the same base.

The final result of the pressure- and temperature-corrected circuit for each main is therefore displayed on a Kent Multelec flow receiver fitted on E-blower panel, and re-transmitted in the summator circuits through selector switches.

Askania automatic-volume-control equipment is incorporated to operate a valve downstream of each of the Dall tubes, so that the proportion of air discharged to each furnace from E blower is at constant volume, irrespective of furnace resistance. The control stations for the Askania equipment are also located on the E-blower panel, which, in addition, mounts the transmitters for the pressure- and temperature-correction circuits, as well as the final corrected-flow transmitters.

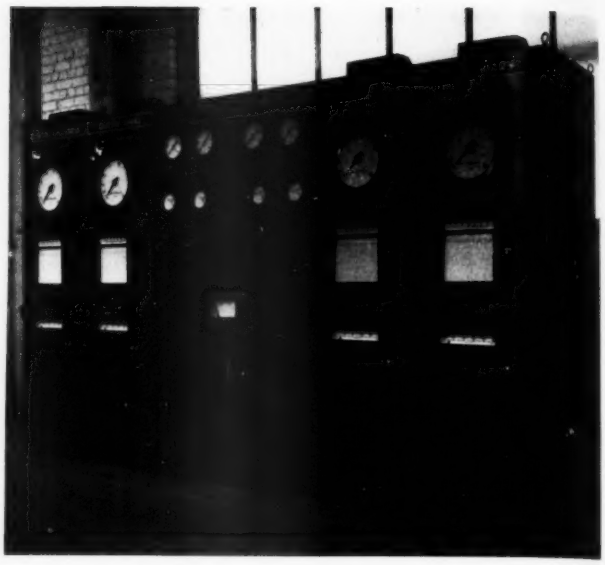
The amount of air contributed by each of the four blowers A, B, C and D, is measured by an inlet Venturi working with a Kent RTE ring-balance transmitter. The output of this transmitter is added to the signal selected from the Multelec pressure- and temperature-corrected flow transmitter associated with the main (and consequently the furnace) to which the particular blower is contributing its air.

The summating instrument is of Multelec pattern, and the two readings are added by potential-addition circuit. This instrument provides local registration of the total air quantity being delivered to a particular furnace, and also transmits to the furnace cast house through selector switching. Panels mounting the individual blower rate-of-flow transmitters and the summating instruments are mounted adjacent to the blower control boards.

The instruments at each furnace are associated with a particular set of pressure- and temperature-corrected instruments, with the result that all the connections for interswitching can be incorporated in one multi-pin plug-and-socket connector.

The 102-in. inlet to E blower is also provided with a fabricated Dall tube to measure the total quantity passing, and this is the largest Dall tube Kent have yet produced. The RTE ring-balance instrument working with this tube operates a Multelec receiver in the blower house to ensure uniformity with instruments on the other blowers, and so that the transmitted output of the Multelec can be interswitched with the outputs from the summating transmitters, to operate a particular set of instruments at the blast furnace and cast house when E blower is on single-furnace duty only.

Additional switching is incorporated on the summation circuits to isolate the pressure- and temperature-corrected set or individual blower-intake instruments. This additional switching is for use if one of the smaller blowers is out of commission and E blower is being used to feed one furnace and also to reinforce the output of another small blower.



Courtesy of the Appleby-Frodingham Steel Co. (Branch of the United Steel Cos., Ltd).

Instrument (split-wind) panel for E blower.

In this case, the additional selector switch can be operated to connect the pressure- and temperature-corrected set to the summator attached to the blower out of commission, and this in turn would re-transmit to the furnace and cast house. Positive isolation of all transmitters not in use is essential, since the minimum limit of transmission is one-seventh of maximum flow.

Further examples of Kent instrumentation and automatic-control equipment are to be found on the turbine and steam-generating plant. The main contractors on the project were Parolle Electrical Plant Co., Ltd., Newcastle upon Tyne, 1.

In the New Year Honours List

(*Continued from page* 93)

W. H. Blaney, Head Packer, National Physical Laboratory.
A. Cameron, Laboratory Mechanic, R.N. Torpedo Experimental Establishment.
W. H. Carabine, Stores Stocktaker, Teeside Bridge and Engineering Co., Ltd.
F. G. Collins, Research and Development Mechanic (Special), Royal Aircraft Establishment.
H. Dean, lately Research and Development Craftsman Special (Inspector), Royal Aircraft Establishment.
O. Edwards, Research and Development Craftsman (Special), Explosives Research and Development Establishment.
J. Foster, Master Stamper, Garringtons, Ltd.
L. N. Howes, Process Supervisor II, Harwell, United Kingdom Atomic Energy Authority.
W. Johnson, Process Supervisor III, Aldermaston, United Kingdom Atomic Energy Authority.
C. G. Jones, Turbine Blader Chargehand, W. H. Allen, Sons and Co., Ltd.
H. Jones, Foreman Electrician, Harland and Wolff, Ltd.
F. C. Mason, Chargehand, Research and Experimental Mechanic, Aldermaston, United Kingdom Atomic Energy Authority.
C. T. Moore, Engraver and Die-sinker, W. R. Royle and Son, Ltd.
J. G. Russell, Research and Development Craftsman (Special) Chargehand, Armament Research and Development Establishment.
T. L. Thompson, Foreman Fitter, Vickers-Armstrongs (Engineers), Ltd.
B. T. Walker, Tool Maker, Thomas Bolton and Sons, Ltd.

NEWS AND ANNOUNCEMENTS

Beilby Memorial Awards

FROM the interest derived from the invested capital of the Sir George Beilby Memorial Fund, at intervals to be determined by the Administrators representing the Royal Institute of Chemistry, the Society of Chemical Industry and the Institute of Metals, awards are made to British investigators in science to mark appreciation of records of distinguished work. Preference is given to investigations relating to the special interests of Sir George Beilby, including problems connected with fuel economy, chemical engineering and metallurgy. The awards are made, not on the result of any competition, but in recognition of continuous work of exceptional merit bearing evidence of distinct advancement in science and practice.

In general, awards are not applicable to workers of established repute, but are granted as an encouragement to younger men who have done original independent work of exceptional merit over a period of years. The Administrators are empowered to make more than one award in a given year if work of sufficient merit by several candidates is brought to their notice. For 1956, an award of 150 guineas was made to Mr. R. W. Kear.

Consideration will be given in due course to the making of an award or awards from the Fund for 1957. Outstanding work of the nature indicated may be brought to the notice of the Administrators, either by persons who desire to recommend the candidate or by the candidate himself, not later than 28th February, 1958, by letter addressed to The Convenor of the Administrators, Sir George Beilby Memorial Fund, The Royal Institute of Chemistry, 30 Russell Square, London, W.C.1. The letter should be accompanied by nine copies of a short statement on the candidates' career (date of birth, education and experience, degrees and other qualifications, special awards, etc., with dates) and of a list of titles, with references, of papers or other works published by the candidate, independently or jointly. Candidates are also advised to forward one reprint of each published paper of which copies are available.

Mond Nickel Fellowships

THE Mond Nickel Fellowships Committee announced recently the award of a Fellowship for 1957 to the following applicants :—

MR. E. J. WILLIAMS (John Summers & Sons, Ltd.) : to study the research and production techniques, quality control and metallurgy of high quality low carbon strip steel in the United Kingdom, the Continent, and the United States.

MR. R. J. D. ACHESON (Mufulira Copper Mines, Ltd.) : to study the extraction and refining processes for copper and allied metals, with particular reference to economic aspects.

The Mond Nickel Fellowships Committee now invites applications for Fellowships of an approximate value of £900 to £1,200 for 1958. Fellowships will be awarded to selected candidates of British nationality, with degree or equivalent qualifications, to enable them to obtain wider experience and additional training in industrial establishments, at home or abroad, to make them more suitable for future employment in senior technical and administrative positions in British metallurgical industries. Each Fellowship will cover one full working year. Applicants will be required to state details of the programme they wish to carry out. Particulars and forms of application are available from The Secretary Mond Nickel Fellowships Committee, 4, Grosvenor Gardens, London, S.W.1. Completed application forms are required by 1st June, 1958.

Graduate Foundry Course

AT present, Great Britain is the only leading industrial country without advanced university training in metal founding. To rectify this state of affairs, the Department of Industrial Metallurgy of Birmingham University is establishing a graduate course dealing specifically with foundry science and engineering. This course will not compete with the course given at the National Foundry College at Wolverhampton, rather its aim and scope will be complementary. The course will be of nine months' duration, leading to a diploma in graduate studies, or one year's duration leading to an M.Sc. degree. At present, it is planned to hold this course every two or three years, with similar graduate courses in other fields of industrial metallurgy in the intervening years. The basic idea underlying the planning of this syllabus is that the course should provide post-graduate training in which the fields of foundry science and foundry technology are carefully balanced. Students will also have the advantage of close contact with research teams active in the field of melting and casting of metals.

Lecture courses will be arranged to meet the requirements of those students taking the full one year course, but one or two brief lecture courses on selected topics will be arranged over short periods in such a way that they could also be attended by extramural students.

The Degree Course has been planned to include eight to ten lectures per week, the remaining time being used for laboratory work, seminars, discussions and works visits.

The inclusive fee for the course is £81, but in certain cases where a student is not sponsored by an employer, the University will consider applications for remission of this fee and, where necessary, for the grant of a maintenance allowance during the period of attendance. Forms of application may be obtained from the Registrar, The University, Edgbaston, Birmingham, 15, and further information about the course from the Secretary of the Department of Industrial Metallurgy at the above address.

Pulse Height Analyser School

A SERIES of one week courses on the use of pulse height analysers is being given by Sunvic Controls, Ltd., at Harlow. The principal object is to provide a detailed knowledge of the circuitry and functioning of the Sunvic pulse height analyser, and special emphasis is laid on servicing and fault finding aspects ; normal routine setting up and operating procedure are also covered. In addition, a study of the instrument's uses in nuclear physics research and radiation spectroscopy, is included, and it is hoped that this will encourage a wider understanding of pulse height analyser technique and applications.

Instruction is divided into six parts and practical work

on the instrument is included in each phase. Three courses have so far been completed, in which students have comprised representatives of both scientific and industrial research establishments, including several outside the U.K. At present, the Company makes only a nominal charge towards the cost of accommodation during the students' stay in Harlow.

Symposium on Corrosion Protection of Motor Vehicles

THE Corrosion Group of the Society of Chemical Industry has arranged a Symposium on " The Protection of Motor Vehicles from Corrosion " to take place at the Institution of Mechanical Engineers, 2 Birdcage Walk, London, S.W.1, on Tuesday, 11th March and Wednesday, 12th March, 1958.

Ten papers dealing with the engine, cooling system, electrical accessories, and bodywork of vehicles, and with packaging for export will be presented for discussion by authorities from the British motor industry and research organisations. Preprints will be available to those registering as participants and paying the conference fee of 10s. for members of the Society of Chemical Industry and 40s. for non-members. Further particulars and forms of registration may be obtained from the Society of Chemical Industry, 14 Belgrave Square, London, S.W.1.

C.D.A. Magazine

THE first issue of a new journal was published recently by the Copper Development Association. Entitled *Copper*, it runs to 24 pages, and is essentially a technical illustrated magazine with articles on a wide range of subjects designed to appeal to all those interested in copper and its alloys.

In an article on Crawley New Town, the story of Crawley's rapid development includes a reference to the use of copper for roofing and plumbing, and a further article shows how copper and its alloys help to reduce household drudgery. Other articles and features deal with the electric smelting of copper, copper oxide rectifiers, steel refining with oxygen, copper and its alloys, and copper and fashion.

R.C.S.T. Metallurgical Club Journal

As the response to the 1956/57 edition of the Metallurgical Club Journal of the Royal College of Science and Technology, Glasgow, C.1, was encouraging, the Publication Committee have decided to produce a further edition, which will appear at the end of March. Copies may be obtained from the Metallurgy Department of the College.

Steel Tube Prices

THE Iron and Steel Board have announced maximum prices for Steel Tubes and Tubulars to the revised B.S. 1387 : 1957. The wall thickness of a number of sizes of medium and heavy Gas List tubes has been amended under the new specification, as a result of which there will on balance be a saving in the weight of steel used per foot of tube. For the majority of sizes, the new prices per foot are lower than those which applied to the old specification, but for certain sizes there are small increases in the prices per foot. On average, the new prices represent a reduction of 3% in the price per foot of Gas List tubes.

Corrosion Congress

THE second congress of the European Federation of Corrosion will be held in Frankfurt from 5th to 8th June, 1958, within the framework of the European Congress of Chemical Engineering, 1958. The various lectures will deal with the types and causes of corrosion in metallic structural materials, the protection of metallic structural materials from corrosion, methods of testing and measurement, and planning and rationalisation. Further particulars may be obtained from the programme of the congress, which, together with an invitation to attend, may be obtained from the congress business office, Gesellschaft Deutscher Chemiker, Frankfurt a.M. 1, Karlstrasse 21 IV, Haus der Chemie.

Patent Information Service

AMENDED rules making minor changes in the arrangements governing patent applications and fees include the introduction of a new service to the public by which information will be supplied as to whether any particular patent is in force, on payment of a nominal fee of 1s. for the first patent and 6d. for each succeeding one. This service will replace, and will, it is hoped, be an improvement on the former annual publication of the List of Patents in Force.

The new rules come into operation on February 1st, and can be obtained from H.M.S.O. and branches, price 2s. 6d. (by post, 2s. 10d.).

Metallurgical Aspects of Semi-Conductors

THE Metal Physics Committee of the Institute of Metals is organising a one-day symposium on " Metallurgical Aspects of Semi-Conductors," to be held on Tuesday, 25th February, 1958, at the College of Technology, Gosta Green, Birmingham. A number of short papers will be presented, but will not be available in advance of the meeting. Visitors will be welcome ; tickets are not required. In conjunction with the meeting, an exhibition is being arranged at the College by the Royal Radar Establishment, Great Malvern. This will be open on 25th February and also on the evening of Monday, 24th February.

Coil Spring Research Conference

THE Annual Conference of the Coil Spring Federation Research Organisation will be held at the Imperial Hotel, Torquay, from Thursday, 5th to Sunday, 8th June, 1958. The business meetings will be held on the morning of Friday, 6th June, and a technical session on the morning of Saturday, 7th June. Other social activities are being arranged during the weekend.

Register of Translators

A REGISTER of translators in the Greater Manchester area, has been compiled on behalf of the libraries of Eccles, Salford, Swinton and Pendlebury, and Urmston, from information supplied by the translators. One hundred and five translators are listed and numbered, and against each name are symbols indicating the type of work, commercial, literary, scientific or technical, preferred. In some cases fees are also specified. The index is so arranged as to make easy the choice of translators willing to undertake work between particular languages.

European Steel and Coal Production

STEEL production for the year 1957 in the European Coal and Steel Community is estimated at some 60 million metric tons, or 5% above the 1956 figure and 43% above that for 1952, the last year before the opening of the common market for coal and steel. From 1956 to 1957, the increase in Community steel production was more rapid than in Great Britain, the U.S., or the U.S.S.R., but Community coal production for 1957 is estimated at 248 million metric tons, or only 3·8% above the 1952 figure and 0·4% below that for 1956. This compares with 1956–1957 increases of some 1% in Great Britain, 10% in the U.S., and 8% in the U.S.S.R.

Personal News

MR. J. L. HARRISON has been appointed Technical Sales Manager of Davy British Oxygen, Ltd., and MR. K. T. BRIGHTMAN has been appointed Assistant Technical Sales Manager. The services of both men will still be available to British Oxygen Gases, Ltd., for advice on the metallurgical uses of oxygen in the manufacture of iron and steel.

AFTER over forty-four years in the active service of Johnson & Phillips, Ltd., MR. L. H. BURTON, Manager of the Contract Department, has retired. He is succeeded by MR. E. F. WARD, who has been the Company's Assistant Contract Manager since 1953. In the same department, MR. J. BENTLEY, becomes Chief Engineer, Construction.

MR. L. H. GADD, has been appointed Financial Accountant to Metal Industries, Ltd. He was formally Chief Internal Auditor of the Parkinson Cowan Group.

MR. D. J. GUILD has recently joined the staff of Armstrong Whitworth (Metal Industries), Ltd., and Jarrow Metal Industries, Ltd., as Technical Representative in the Midlands Area. where he will assist the Companies' Midlands Manager, MR. J. BELL, and will operate from their offices at Somerset House, Temple Street, Birmingham, 2.

MR. A. V. TIDDY, Assistant Secretary of Samuel Osborn & Co., Ltd., has been appointed to the position of Local Director.

MR. A. P. GAGNEBIN and MR. L. E. GRUBB have been appointed Assistant Vice-Presidents of The International Nickel Co. Inc. Mr. Gagnebin continues as Manager of the Nickel Sales Department, and Mr. Grubb, who has been General Superintendent of the Huntington, West Virginia, Works of International Nickel since May, 1953, will be in charge of labour relations at all United States plants.

BRITISH DRIVER-HARRIS CO., LTD., manufacturers of the Nichrome series of electrical alloys, have announced the following promotions: MR. H. E. R. THOMAS, for several years Assistant Sales Manager, becomes Sales Manager; MR. H. KAY, who has been with the Company for ten years, in the accounting and costing departments, becomes Chief Accountant; and MR. H. J. ANDREW, who has twenty years' service, rises to the position of Assistant Secretary. MR. T. SCHOFIELD, takes on a new appointment as Technical Assistant to the Managing Director, after thirty years with the Company; and MR. A. SARGEANT, also with thirty years' service, is promoted to Wire Mill Manager.

THE Effingham Steel Works, Ltd., announce that MR. R. LLOYD, who is in charge of their London office, and MR. J. H. ALLAN, the General Manager, have been elected Directors of the Company.

MR. E. PEARSON has been appointed Assistant Sales Manager of Fielden Electronics, Ltd., responsible for all internal and external staff associated with the Sales Department. MR. G. ENSOR, General Manager of the Company, has now resumed the office of Sales Manager in addition to his other duties.

METROPOLITAN-VICKERS ELECTRICAL CO., LTD., announce the appointment of MR. A. O. AHLQUIST as Sales Manager, Mechanical Department. He succeeds MR. H. LAWSON-JONES, who will act in an advisory capacity, and who is transferred to Sales Management.

MR. S. A. DOHM, Chairman of the Dohm Group is at present on a six-week trip to Africa. The Dohm Group, which is interested in steel and minerals, and whose factories export products ranging from plastics to corrugated iron, was founded twenty years ago by Danish-born Mr. Dohm.

MR. J. E. C. BAILEY, C.B.E., Chairman and Managing Director of Baird and Tatlock (London), Ltd., and Hopkin and Williams, Ltd., is on a visit to the Companies' branches, agents and representatives in Rhodesia, South Africa, Australia, New Zealand, Singapore and Ceylon.

MR. W. T. VIZER-HARMER, at present Director and Commercial Manager of Steel, Peech and Tozer (Branch of The United Steel Cos., Ltd.), has been appointed Commercial Director of the Branch. He will be succeeded as Commercial Manager by MR. J. MACKENZIE-MAIR.

MR. R. J. KINGSNORTH, has recently been appointed Manager of the Process Control Division of Elliott Brothers (London), Ltd., a member of the Elliott-Automation Group. Mr. Kingsnorth has, for the past seventeen years, been Manager of the Erith Instrument Factory of Salford Electrical Instruments, Ltd.

MR. G. H. BUCHANAN, who for the past fourteen years, has been the Representative in Scotland for Craven Brothers (Manchester), Ltd., retired on December 31st. He will be succeeded by MR. H. PROBERT, who will also be in charge of the Company's new Scottish Office at 157, West George Street, Glasgow, C.2. (Tel.: City 5285).

MR. E. C. PATTERSON, a Vice-President of J.P. Morgan & Co., Inc., has been elected a Director of The International Nickel Co. of Canada, Ltd.

MR. R. D. PARKER, Vice-President in charge of Canadian operations of The International Nickel Co. of Canada, Ltd., is moving his headquarters from Copper Cliff, Ontario, to the Company's offices in Toronto.

VICKERS-ARMSTRONGS (Shipbuilders), LTD., announce that MR. R. J. W. RUDKIN, has been appointed General Manager, Naval Yard. He will be directly responsible to the Shipbuilding General Manager of the Company.

VICKERS, LTD., announce that MR. A. H. HIRD, has been appointed to the Board of Directors. Mr. Hird has been with the Group for almost forty years, and is a Director of Vickers-Armstrongs, Ltd., and Metropolitan-Cammell Carriage & Wagon Co., Ltd., and Chairman of several wholly-owned subsidiaries of Vickers, Ltd.

Messrs. R. H. Waddington, J. C. Parlee, R. A. Cabell, and P. Queneau have been elected Assistant Vice-Presidents of The International Nickel Co. of Canada, Ltd. Mr. Waddington has also been appointed General Manager of The Parent Company's Ontario Division, and Mr. Parlee, General Manager of its Manitoba Division. Messrs. Cabell and Queneau have been elected also as Vice-Presidents of The International Nickel Co., Inc., The United States Subsidiary of the Company.

British Insulated Callender's Cables, Ltd., announce the appointment of Mr. A. F. Miller, as Manager of the Aberdeen Branch Office and Mr. L. R. Clewworth, as Manager of the Newcastle Branch Office.

The United Steel Cos., Ltd., announce the following appointments: Mr. K. G. Lampson, Managing Director (Sales) of United Steel Cos., Ltd., Lt.-Col. P. F. Benton Jones, Managing Director (Mining and Carbonisation) of United Steel Cos., Ltd., Lt.-Commander G. W. Wells, Director and General Manager of Appleby-Frodingham Steel Co., and Mr. R. J. Bavister, Commercial Manager of Samuel Fox and Co., Ltd., have been appointed Directors of Samuel Fox. Mr. K. G. Lampson, Lt.-Col. P. F. Benton Jones and Mr. I. M. Kemp, Chief Design Engineer of Appleby-Frodingham Steel Co., have been appointed Directors of Appleby-Frodingham. Mr. R. P. Crawshaw, General Sales Manager and Chief Purchasing Agent of United Steel, has been appointed a Director of United Steel Structural Co., Ltd.

Mr. K. Druce, has been appointed Manager of the Bristol Office of The English Electric Co., Ltd., responsible for the South-West of England territory, in succession to Mr. T. Robinson, who retired on 31st December, 1957. Following the retirement of Mr. I. Mackintosh, on the same date, Mr. H. Granville-Brown, has taken charge of the Southampton Office of the Company, which has moved to new premises at 29 Shirley Road, Southampton (Tel.: Southampton 28333/3).

Mr. R. F. Hayman, Industrial Gas Officer of the Gas Council, has been appointed Chairman of the Industrial Gas Development Committee of the Council in succession to Mr. W. H. Tarn.

Edgar Allen & Co., Ltd., announce the appointment of Dr. A. D. Merriman, G.C., O.B.E., D.L., formerly Secretary of the Institution of Metallurgists, as Consultant on Scientific Projects.

Mr. Spence Sanders has retired from the Board of Almin, Ltd., of which he has been a Director since its formation in 1945. He has also relinquished his Directorship of other Companies in the Almin Group, including International Alloys, Ltd., Southern Forge, Ltd., Warwick Production Co., Ltd., and the Fulmer Research Institute, but he will continue with the Group in the capacity of Group Consultant. His place as Chairman of the Fulmer Research Institute has been taken by Mr. W. R. Merton, and Mr. J. G. Graham has been appointed to the Board of the Institute.

Mr. M. F. Dowding has been appointed Chief Engineer of Davy and United Engineering Co., Ltd., in succession to Mr. W. W. Franklin, whose sudden death on 18th December is referred to below. A Cambridge graduate, Mr. Dowding received his practical training in the Company and has been Engineering Sales Manager since 1950. Mr. A. A. Thomas succeeds Mr. Dowding as Engineering Sales Manager.

Mr. W. Brining has relinquished his appointment as Secretary of Almin, Ltd., which he has held since the formation of the Company in 1945, and is succeeded by the Assistant Secretary, Mr. A. E. Roe. Mr. Brining continues as a Director of Almin, Ltd., and of its subsidiary companies, Southern Forge, Ltd., Warwick Production Co., Ltd., Aero Controls, Ltd., Pressoturn Ltd., and others.

Obituary

We regret to record the deaths of the following:—

Mr. W. W. Franklin, Technical Director of Davy and United Engineering Co., Ltd., who died suddenly at his home at Ashford-in-the-Water, Derbyshire, at the age of 57. Mr. Franklin served his apprenticeship with Davy-United and, apart from service in the Royal Navy during the 1914–18 War, spent his entire career with the Company. In 1931, he took charge of the Estimating Drawing Office, later becoming Rolling Mill Department Manager and Proposal Manager. In July, 1947, he became Chief Engineer of Davy-United and then in 1951 was appointed to the Board of the Company as Technical Director. Mr. Franklin's reputation as a leading rolling mill engineer was firmly established, particularly in the field of section rolling, and the majority of the important new plants installed in Britain under the steel industry's post-war development schemes were engineered under his direct personal supervision.

Mr. W. B. H. Gallwey, who died suddenly on 14th December, 1957, at his home at Cobham, Surrey. Mr. Gallwey was Chairman and Managing Director, Union Carbide, Ltd.; Chairman, British Acheson Electrodes, Ltd.; Chairman and Managing Director, Gemec, Ltd., and Kemet Products, Ltd.; and a Director of Bakelite, Ltd.

Mr. H. Matthews, Joint Managing Director of Crofts (Engineers), Ltd., who died suddenly on Saturday, 28th December, 1957.

Mr. Alastair McLeod, Head of the Metallurgical Editorial Staff of Industrial Newspapers, Ltd., who died suddenly in Charing Cross Hospital on Friday, 3rd January, 1958, at the age of 58. Specially interested in rolling mill practice, Mr. McLeod received his metallurgical training in Scotland, and was for many years with Frederick Braby & Co., Ltd., Glasgow, and other Scottish rollers of sheet steel, before moving to London to take up the Editorship of *Sheet Metal Industries*. At the time of his death he was Managing Editor of *Sheet Metal Industries*, *Metal Finishing Journal*, and *Metal Treatment and Drop Forging*, and Chief Metallurgical Editor of *Iron and Coal Trades Review*.

Mr. McLeod travelled extensively in the course of his work and was well known and esteemed in metallurgical circles throughout the United Kingdom and on the Continent of Europe. He was a Fellow of the Institution of Metallurgists, an Hon. Vice-President of the Institute of Sheet Metal Engineering, which he was largely instrumental in founding, and a member of numerous technical societies in the metallurgical field.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Temperature Recorder

ETHER, LTD., have recently introduced an instrument which records any number of independent temperature points from one to six. This recorder incorporates a conventional galvanometer, a chart and chart-drive mechanism, recording mechanism, automatic ribbon-mechanism, and an automatic station selector and indicator.

The recording chart has a calibrated width of 6 in. At a speed of 1 in./hr., it runs continuously for 30 days, and it will also run at speeds of $\frac{1}{2}$ in./hr. or 2 in./hr., if desired. The chart is fed over frontal nylon drive wheels powered by a 220/250 V. synchronous electric motor, which also drives the recording mechanism. Easy loading is ensured by the presence of a hinged-front top-plate which pulls down and gives access to the chart roll.

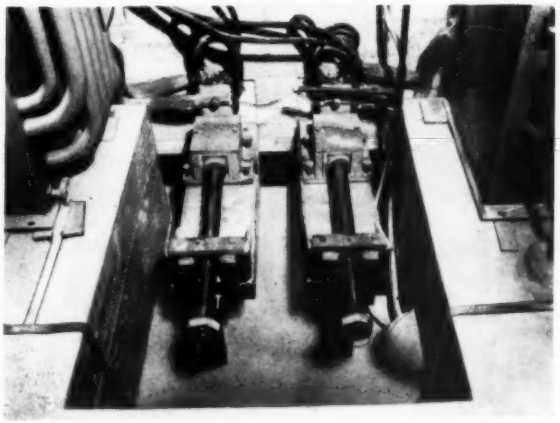
A lightweight chopper-bar, with calibrated scale attached, is fitted above a knife-edged galvanometer pointer. Through the action of a timing cam and gear train, the chopper-bar strikes the pointer at given intervals and imprints a small, coloured dot through the ribbon on to the recording-chart. The knife-edged pointer is attached to the galvanometer coil by means of a flexible metallic strip, which reduces the disturbance and load to the precision-ground pivots at the impact of the chopper-bar. The galvanometer is fitted with an Alcomax II magnet, a high-resistance coil, precision-ground hardened pivots and spring-loaded polished sapphire jewels, all of which help to ensure an accurate performance, even under severe operating conditions.

A completely new scanner-commutator with high-grade nickel-silver contacts is another interesting feature. This commutator has been tested under severe conditions and shows no variation in contact-resistance after 5×10^6 revolutions. In fact, only after 10^7 revolutions is servicing necessary. The light-alloy chassis, upon which the recorder assembly and galvanometer are mounted, is hinged and can be swung out from the main case, to facilitate easy inspection and servicing.

Ether. Ltd., Tyburn Road, Erdington Birmingham, 24.

Continuing Graphite Electrode Salt Baths

THE main advantage of the Efco-Upton continuing graphite electrode salt bath—recently introduced into this country by Electric Resistance Furnace Co., Ltd., and based upon several years research and proving tests by their associates, Upton Electric Furnaces, Ltd., Detroit, U.S.A.—is the ability to renew electrodes without taking down any part of the furnace brickwork. The electrodes consist of cylindrical graphite rods which are fed horizontally through opposing walls at the bottom of the refractory lining as they are consumed, and whilst the furnace is still in operation. Moreover, a fresh electrode can be attached to the screw feed device again without interrupting operation of the plant; this means that the full life of the furnace lining can be utilised, an advantage which has never before been possible with submerged electrodes. Since the electrodes are submerged with the end faces only exposed to the salt,



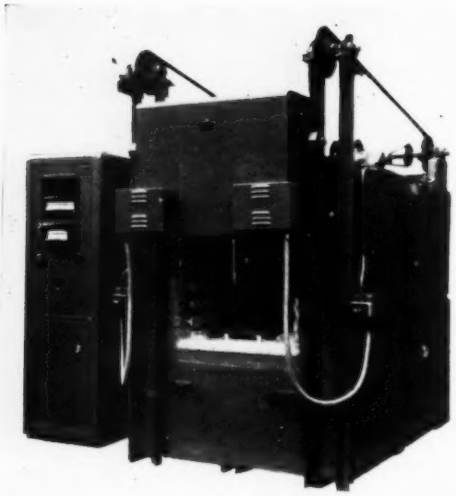
electrode wear is reduced to a minimum and their life increased.

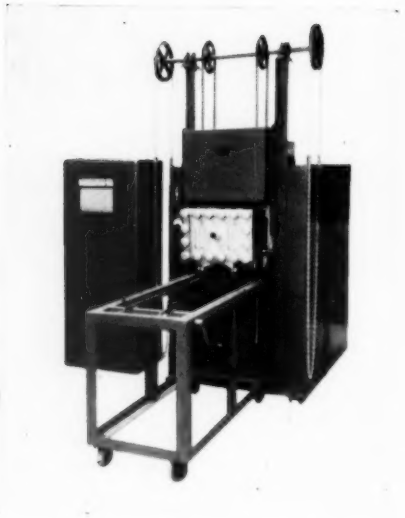
With the special dense high-temperature bricks which are used, a lining life of twelve to eighteen months is achieved at high-speed steel hardening temperatures, three years on neutral hardening up to 1,000° C., and on aluminium brazing a life of five to ten years is not uncommon. In addition, the special lining bricks used result in a negligible amount of salt absorbtion into the lining whereas, with conventional refractory linings, practically the same volume of salt is absorbed by the brickwork as is contained in the actual pot. This point is of particular importance in high speed and brazing baths where the salt (or flux) is a comparatively expensive item. Another, perhaps slightly less obvious, advantage is that with the electrodes located in the very bottom of the bath, the entire exposed surface of the salt and operating depth is available as work space. Again, the absence of any metal, resulting in the presence of metallic oxides in the bath, facilitates maintenance of the neutrality of the salt in hardening operations, and obviates premature breakdown of the flux in aluminium brazing. Size for size, the price is stated to be no greater than that of a conventional electrode type salt bath.

Electric Resistance Furnace Co., Ltd., Netherby, Queens Road, Weybridge, Surrey.

"Compound" Water Meters

GEORGE KENT, LTD., announce the introduction of an entirely new class of trade water meters, known as the "Compound," for the measurement of widely varying cold-water flows. The Compound meter, which supersedes the well-known Torrent Combination meter, has an extremely wide measuring range, which in the case of the 3 in. is over 500 : 1 within accuracy limits of 2%. To achieve this exceptional range, two completely separate measuring units are used, one for high and the other for low flows, both of which, with an automatic change-over valve to select the unit required, are contained in a single compact meter body. Only one measuring unit can register at a time.





These meters are made in 3-in. and 4-in. pipeline sizes and have the same body length and flanges as the corresponding Torrent Combination meters. Durable, corrosion-resisting materials are used in their construction, and all meters are subjected to a test pressure of 300 lb./sq. in. The meters use established Kent measuring units, and all components are interchangeable. The complete absence of any external piping greatly simplifies installation and maintenance, the latter being further eased by the fact that all parts are easily removed for servicing without breaking any pipe-flange joints.

George Kent, Ltd., Luton, Bedfordshire.

Heavy Duty Box Furnace

HEDIN, LTD., now include in their range of furnaces a general-purpose heavy-duty box-type unit. The left-hand illustration shows a typical example, with internal dimensions of 54 in. × 24 in. × 18 in. It is rated at 60 kW. and has a maximum working temperature of 1,150° C.

Features of special interest are the press-button-operated door, non-distorting hearth and extremely efficient thermal insulation. The heating elements are in heavy section 80–20 nickel-chromium and operate on a low voltage supply from a transformer. Elements are fitted into the door, as well as the walls of the heating chamber, to ensure an even temperature throughout.

The temperature control system is fully automatic and includes safety devices which provide a protection for the charge as well as the heating elements. A further safety measure is the inclusion of a second contactor, which takes over in the event of the contacts sticking on the operating contactor. There is also an E.A.C. single phase preventor. In the event of one phase being affected, this instrument immediately cuts the other two phases, thereby preventing an out-of-balance load. The whole of this equipment is housed in a floor mounted cubicle.

A range of atmosphere and vacuum containers is available for use with these furnaces for the treatment of both ferrous and non-ferrous metals. A typical unit, complete with container and charging trolley is seen in the illustration on the right. This is the hand-operated version, but power-operated models are available as standard equipment.

When these furnaces are used in conjunction with an atmosphere or vacuum, the containers are designed to suit whatever application is required. For example, if a hydrogen or nitrogen atmosphere is to be used, the trolley is equipped with the necessary gauges, and accommodation is provided on the trolley for gas cylinders. This gives a self-contained unit that can be completely removed for cooling purposes, leaving the furnace free for another charge. Vacuum containers are constructed for high vacuum and the vacuum equipment is housed within the framework of the trolley,

These furnaces are suitable for a wide range of heat treatment operations, and vitreous enamelling has also been carried out successfully in them. Typical applications for container work include bright annealing, degassing, copper brazing, and sintering.

Hedin, Ltd., Commerce Estate, South Woodford, London, E.18.

98% Grade Vanadium Oxide

A NEW 98% grade vanadium oxide will be of special interest to ferro alloy producers and manufacturers of ferrous and non-ferrous alloys. The new grade represents a marked improvement over former grades, which average 86–89% vanadium pentoxide. The reduction of alkali oxide content to not more than 2% is important to furnace operations, because of the appreciable elimination of fume hazards caused by these oxides.

The 98% vanadium oxide also offers advantages in reduced sulphur content, silica content and other contaminants which have a direct bearing on the production of high-quality vanadium steels. It is expected that the availability of this high-grade vanadium oxide in commercial quantities will spur further advances in the use of vanadium as an alloying component. The new grade is available in either a dense fused form, suitable for direct addition to an alloy furnace, or in granular form.

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LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

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Rapid Titrimetric Analysis of White Metals

By L. J. Ottendorfer

Institute of Inorganic and Analytical Chemistry, The University of Technology, Vienna

Results of high accuracy are obtained in less than an hour in the analysis of alloys of antimony, tin, lead and copper, by a combination of bromatometric methods (for antimony and tin) with complexometric methods (for lead and copper).

LEAD can be titrated complexometrically in ammonium tartrate solution at a *p*H of about 10. The most favourable results are obtained by adding standard E.D.T.A. (ethylene diamine tetra acetic acid) solution in excess, and back-titrating with standard nickel solution, using Murexide as the indicator.

Antimony and tin, present as their tartaric acid complexes, do not interfere under those conditions, and interference by copper can be eliminated by addition of potassium cyanide, using standard calcium or magnesium solution for the back-titration. Both lead and copper can be estimated accordingly by a differential method.

A complete titrimetric analysis of alloys of antimony, tin, lead and copper can be effected by a combination of bromatometric methods (for antimony and tin) with complexometric methods (for lead and copper). Results of high accuracy are obtained in less than one hour.

Reagents Required

Standard E.D.T.A. Solution—M/20.
Standard Nickel Solution—M/20.
Standard Calcium or Magnesium Solution—M/20.
Standard Potassium Bromate Solution—N/10.
Potassium Cyanide Solution—20%.
Sodium Hydroxide Solution—20%
Ammonium Tartrate Solution—Dissolve 200 g. Analar tartaric acid in 400 ml. water, add 330 ml. 0·88 s.g. ammonia solution, and dilute to 1 litre with water.
Indicators—Methyl orange, Eriochrome Black T, Murexide.

All the solutions should be made with water free of calcium or magnesium, preferably obtained from a quartz still or purified by ion exchange. Solutions should be stored in polyethylene bottles if used over long periods.

Determination of Lead in Alloys of Lead, Antimony and Tin

0·5 g. of the sample is placed in a 150 ml. conical flask and dissolved in 20 ml. of a mixture of 5 vol. concentrated hydrochloric and 1 vol. concentrated nitric acid by warming on a steam bath. As soon as the sample has been dissolved, 20 ml. of tartrate solution are added immediately, followed by another 15 ml. of 0·88 s.g. ammonia solution after slight cooling: there should be no precipitate or turbidity at this stage.

TABLE I.—RESULTS OF LEAD DETERMINATIONS.

Sample Number	Alloy	Sample Weight (g.)	Weight of Lead Calculated (mg.)	Weight of Lead Found (mg.)	Error (% Lead)
1	Pb 10·64% Sn 89·30%	0·5038	53·60	53·46	−0·3
2	Pb 52·61% Sn 47·32%	0·5027	264·8	265·2	+0·15
3	Pb 80·37% Sn 19·53%	0·5011	402·7	403·2	+0·1
4	Pb 3·84% Sb 96·12%	0·5041	19·36	19·79	+0·1
5	Pb 52·10% Sb 47·85%	0·5023	261·7	261·4	−0·06
6	Pb 95·78% Sb 4·19%	0·5010	479·9	480·1	+0·04

The ammoniacal solution is boiled for two minutes to destroy any oxidising anions, cooled to room temperature and transferred to a 500 ml. titration flask. A *p*H of about 10 is obtained by addition of about 20 ml. of 1 : 4 ammonia solution.

Depending on the amount of lead anticipated, standard M/20 E.D.T.A. solution is added in a sufficient excess to give a satisfactory back-titration. The excess is titrated with M/20 nickel solution and Murexide indicator. The indicator action is sluggish near the end-point, but if the titration is carried out slowly over the last few drops, the position of the end-point is clearly defined.

1 ml. M/20 E.D.T.A. = 0·010361 g. lead

Note.—Direct titration of lead in the presence of antimony and tin gives erratic end-points. Back-titration with standard zinc solution gives an irreversible colour-change of the Eriochrome Black T indicator at the end-point.

Complete Analysis of Alloys of Lead, Antimony, Tin and Copper

0·5 g. of the sample is placed in a covered 200 ml. beaker and dissolved in 10–15 ml. of concentrated sulphuric acid by heating until sulphur trioxide fumes appear. Fuming is continued in the open beaker for two minutes to remove sulphur dioxide. After cooling, 20 ml. of water are added, followed by 20 ml. of concentrated hydrochloric acid, which should be poured over the watch-glass. Another 100 ml. of hot water are added, and antimony[III] is titrated with N/10 potassium bromate, using methyl orange as indicator. The pre-

TABLE II.—RESULTS OF ANALYSES OF WHITE METALS.

Alloy Number	Actual Composition (%)	Composition Found (%)	Error (%)
1	Pb 13·58	13·48	−0·10
	Cu 7·35	7·30	−0·05
	Sb 10·21	10·13	−0·08
	Sn 68·83	68·90	+0·07
	99·97	99·81	
2	Pb 54·31	54·41	+0·10
	Cu 3·90	4·02	+0·12
	Sb 11·64	11·76	+0·12
	Sn 30·11	29·96	−0·15
	99·96	100·15	
3	Pb 70·87	70·99	+0·12
	Cu 0·76	0·82	+0·06
	Sb 15·62	15·70	+0·08
	Sn 12·71	12·53	−0·18
	99·96	100·04	

cipitate of lead sulphate which is suspended in the liquid does not interfere ; the end-point can be recognised very accurately, and it is reached when the last pink shade disappears. Near to the end-point the titration should be carried out slowly, and a temperature of 70° C. should be maintained.

1 ml. N/10 potassium bromate = 0·006088 g. antimony.

The precipitate of lead sulphate is now dissolved by the addition of 20 ml. of tartrate solution and, if necessary, by gentle warming. The clear solution is brought to a *p*H of about 10 by addition of 20% caustic soda (checked on wide range indicator paper) and transferred to a 250 ml. volumetric flask.

After having cooled to room temperature, the flask is filled to the mark and two equal parts of 50 or 100 ml. are taken with the same pipette. They are placed into two 500 ml. titration flasks *A* and *B*.

A is used first for the titration of the sum of lead and copper, and later on for the titration of tin[II], while *B* is used for the titration of lead only. In this case, copper is masked by addition of potassium cyanide.

Flask A—An excess of E.D.T.A. solution, 5 ml. of buffer solution (*p*H = 10) and 300 ml. of water are added to the sample, and the excess of E.D.T.A. is back-titrated with standard nickel solution, using Murexide as indicator. The amount of E.D.T.A. consumed by lead and copper is recorded as *a*.

The solution is now transferred to a 1-litre conical flask and acidified with concentrated hydrochloric acid. An excess of 50 ml. hydrochloric acid is added and the flask is placed on a water bath. Reduction to tin[II] is effected at a temperature of about 70° C. by addition of iron powder (reduced by hydrogen). Three portions of about 2 g. added after intervals of five minutes should be sufficient. To prevent re-oxidation, the flask is closed with a Contat-Gloeckel trap filled with saturated sodium bicarbonate solution. As soon as the iron powder has dissolved, the solution is cooled as quickly as possible and filtered over glass wool to remove the antimony which has been reduced to the metal stage. The filtrate is collected in another 1 litre conical flask, in which a piece of marble and a few ml. of dilute hydrochloric acid produce sufficient carbon dioxide to protect tin[II] from oxidation.

Tin[II] can be titrated with either N/10 standard iodine, or N/10 standard potassium bromate and addition of 10 ml. of potassium iodide solution ; starch or thyodene is used as indicator.

1 ml. standard solution N/10 = 0·005935 g. tin.

Flask B—In this part of the sample, lead has to be titrated exclusively, and thus copper has to be converted into the cyanide complex, which does not react with E.D.T.A. As nickel would give a similar complex, it cannot be used for back titration, and standard calcium or magnesium solution may be used instead. Calcium solution in combination with Murexide indicator gives a reversible end-point, but not a very abrupt change of colour, while magnesium and Eriochrome Black T result in an irreversible end-point with a very distinct colour change.

20% potassium cyanide solution is added to the sample until the blue colour of copper has disappeared, followed by another 0·5 ml. The same volume of E.D.T.A. as used in flask *A* is added, and back titration is carried out with standard calcium or magnesium solution.

The amount of E.D.T.A. consumed by lead only, is recorded as *b*.

1 ml. M/20 E.D.T.A. = 0·010361 g. lead.

a − *b* yields the amount of copper.

1 ml. M/20 E.D.T.A. = 0·003178 g. of copper.

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ISCOR Expansion

THE continued expansion of the South African Iron and Steel Industrial Corporation is examined in the current issue of Barclays Bank D.C.O.'s *Overseas Review*. Last year ISCOR produced steel which, if it had been imported, would have cost South Africa £68 million in foreign exchange, and the total sales of all products, including pig iron and by-products, were valued at more than £44 million.

The Corporation has decided to increase the rated capacity of its plants by approximately 900,000 tons, which will bring ISCOR'S total rated capacity to 2,350,000 ingot tons per annum. Capital extensions, based on present prices and estimates, will cost some £56 million. The Corporation is now looking for a site for a third steelworks.

B.S.C.R.A. Melting Furnace Film

A 16 mm. sound film on the 6 cwt. capacity carbon-rod resistor furnace which is installed at the experimental foundry of the British Steel Castings Research Association has been made by the Association's own film unit. Originally produced a few weeks ago to illustrate the inaugural lecture of the recently announced exchange series between the B.S.C.R.A. and the Steel Founders' Society of America, this 15 minute film describes in detail the construction and operation of this steelmaking furnace, which was the first of its type to be ordered for installation in this country. The film is available to non-members of the Association at a hire charge of £5 5s. 0d. on application to the Secretary of the Association at East Bank Road, Sheffield, 2.

Electrolytic Polishing

New Equipment with Provision for Circulating the Electrolyte

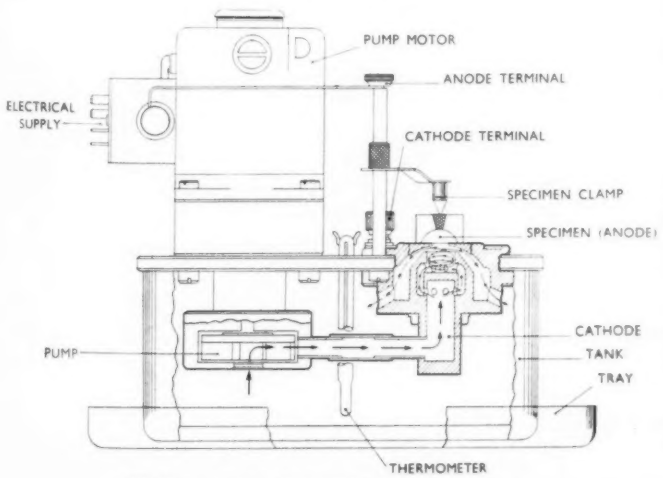
General view of the Shandon equipment, showing the power supply on the left and the polishing unit on the right.

THE electrolytic technique of polishing metal specimens for microscopic examination, based on the pioneer work of Jacquet, is finding increasing application. In this method, the specimen, ground on successive grades of abrasive paper, is finally made the anode in an electrolytic cell, when continued solution of the metal occurs in such a way that irregularities in the surface are removed and it becomes smooth and bright.

A number of advantages are claimed for electrolytic polishing as compared with the mechanical method of carrying out the operation. The deformed metal at the surface of the specimen can be removed completely, revealing the true structure, and this may take as little as 20 seconds. Furthermore, etching can be effected in many cases, merely by lowering the current density for a few seconds at the end of the treatment. Electrolytic etching is often superior to the normal methods of immersion or swabbing, particularly in the case of corrosion-resistant materials. The complete removal of fine scratches claimed for the electrolytic method is advantageous in high power microscopy, and for specimens having grain and deformation structures best examined in polarised light, it may be essential to electropolish.

Electropolishing gives best results on pure metals or single phase alloys, as there may be some differential attack between the phases of multi-phase alloys, due to their different rates of solution. Marked pitting is often produced when non-metallic inclusions are present, but, on the other hand, the differential attack may be useful as a sensitive method for the detection of very small amounts of insoluble constituents or of precipitated phases.

Under polishing conditions, the specimen becomes covered with a layer of reaction products, and the rate-determining factor appears to be one of diffusion in this layer. At peaks in the surface the layer is thicker and the concentration gradient lower, leading to preferential solution of the peaks, and thus to smoothing. If the layer becomes too thick, the smoothing process slows and may even cease, and some form of agitation of the electrolyte is necessary to maintain the layer at the optimum thickness for polishing.



Diagrammatic view of the polishing unit.

A new electropolisher introduced recently by Shandon Scientific Co., Ltd., is based on apparatus developed in the Metallurgy Division of the Atomic Energy Research Establishment at Harwell,* and is characterised by a method of dispersing the anode layer which results in complete freedom from flow lines. This is achieved by pumping the electrolyte through a series of orifices so that it contacts the specimen in the form of a rotating and continuously renewed vertical liquid column.

The polishing unit consists of an electrolyte tank surmounted by a polishing deck. The tank is made of glass and measures 7 × 5 × 3 in.

* Sykes, Haddrell, Harris and Mott. *J. Inst. Metals*, 1954–55, **83**, 166.

high, the size having been chosen to provide a large surface area to facilitate heat dispersion and yet keep the volume of electrolyte as small as possible. Any spillage is collected in a PVC tray in which the tank rests.

The rigid PVC polishing deck rests on the tank, and supports the motor driven centrifugal pump, the right-angle thermometer, the specimen clamp, and the electrolytic cell. The pump is made from PVC and polythene and is directly driven by a motor protected from spillage and fumes. Connected to the pump by a short length of PVC tubing is the electrolytic cell, incorporating the specially formed stainless steel cathode. The electrolyte, supplied by the pump, is forced through two series of holes, tangentially drilled round the cathode, with the result that it forms in the upper cathode chamber a rotating liquid column, vertically impinging on the cathode, as mentioned above. The specimen is held in position on a removable PVC mask by a spring-loaded clamp which makes the electrical connection to the specimen.

The power unit provides a D.C. polishing supply of 250 W. (e.g., 50 V. at 5 A. max.), and an etching supply of 5 V. at 0·5 A. max, both smoothly variable from zero. An A.C. output, incorporating a rheostat, is provided for driving and controlling the speed of the electric pump. Functionally the power supply is arranged for either manual or automatic operation, according to the position of the corresponding selector switch. On " manual," all switches are independently and separately controlled by on/off switches. For operation on " automatic," the time switch is set to the required polishing period (within a range of 1–90 seconds). At the end of the period, both the pump and D.C. are automatically switched off. Electrolytic etching can be carried out as part of the operation by switching to " etch " during the last seconds of the cycle.

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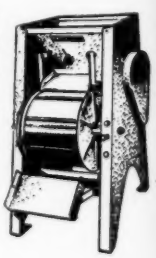

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